KAPLAN

MEDICAL

Nephrology

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Acute Renal Failure: Prerenal & Postrenal

Acute Renal Failure— Definitions

- Rapid ↑ in BUN or creatinine
- Can occur over several hours, days or weeks
- Some causes of ARF include:

Several Hours	***Several Weeks***
Rhabdomyolysis	Aminoglycosides
Contrast induced	Poststreptococcal glomerulonephritis

Acute Renal Failure— Definitions

- Renal insufficiency (azotemia)
  1. Renal failure that does not usually require dialysis
  2. Build-up of azole groups or nitrogens in the blood
- Uremia (end stage renal disease)
  1. Severe renal failure requiring dialysis
  2. Severe acidosis and fluid overload
  3. Altered mental status
  4. Hyperkalemia
  5. Anemia
  6. Hypocalcemia
  7. Pericarditis

Acute Renal Failure— Definitions

- Also defined by the *site of the defect*
  1. Pre-renal
     - Decreased perfusion
  2. Intra-renal
     - Tubular or glomerular defect
  3. Post-renal
     - Decreased drainage or flow

Acute Renal Failure— Diagnosis

- ↑ BUN regardless of cause
- May be falsely elevated with increased dietary protein or GI bleeding
  1. Derived from protein catabolism
  2. Increases with the severity of renal failure
- May be falsely decreased with liver disease, malnutrition or SIADH

Acute Renal Failure— Diagnosis

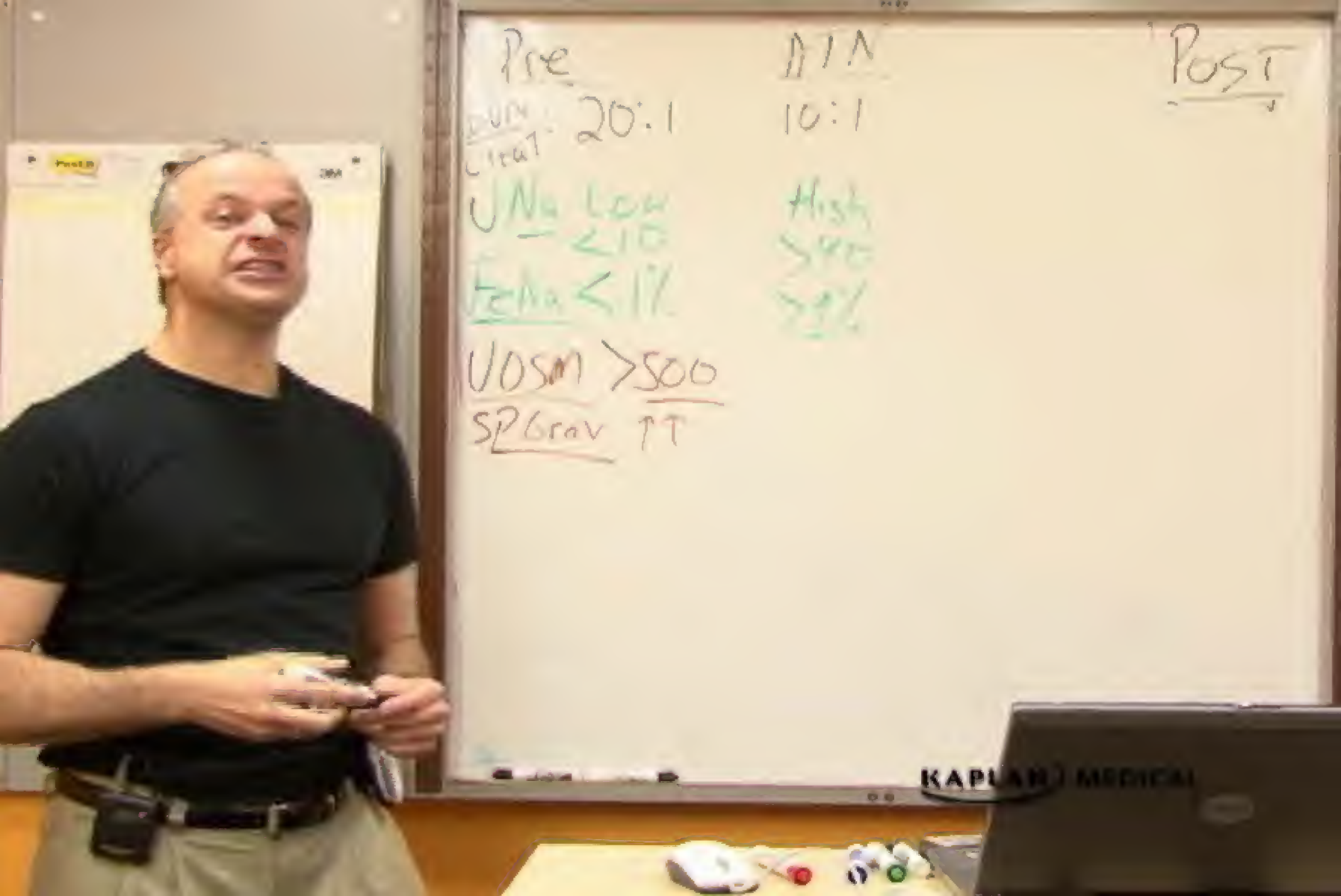
- Creatinine is the main measure of renal *function*
- Creatinine clearance approximates the GFR
  1. Slightly overestimates
  2. Always adjusted for weight
- May be falsely low with decreased muscle mass and increased in body builders
- Increases at maximum rate of 0.5 to 1.0/day

Prerenal Azotemia— Definitions

- Diminished perfusion
- Kidneys are intrinsically normal
- Causes include:
  1. Hypovolemia regardless of etiology
  2. Hypotension regardless of etiology
  3. Decreased cardiac output
  4. Third spacing
  5. Decreased albumin

Prerenal Azotemia— Diagnosis

- BUN to creatinine ratio of 20:1
- ↓ urine sodium
- ↓ fractional excretion of sodium
- ↑ urine osmolality (>500)
- SG >1.010


Pre
AIN
Post
BUN/Creat: 20:1
10:1
UNa Low
<10
High
>40
FeNa <1%
>1%
UOsm >500
SP Grav ↑↑
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Prerenal Azotemia— Hepatorenal Syndrome

- Intense vasoconstriction of afferent arterioles → decreased renal perfusion
- Findings are consistent with prerenal azotemia
- Correct underlying liver disease

Prerenal Failure— The Effect of ACE Inhibitors

- Vasodilation of the efferent arteriole
- Transient decrease in GFR
- Effects are exaggerated in
  1. The elderly
  2. Diabetics
  3. HTN
  4. Baseline renal disease
- Overall effect is decreasing the rate of progression to uremia and renal failure


Pre
DIN
10:1
Post
ACE
ATII
10
AI
Relase
NSAID
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Prerenal Failure— The Effect of ACE Inhibitors

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- Transient decrease in GFR
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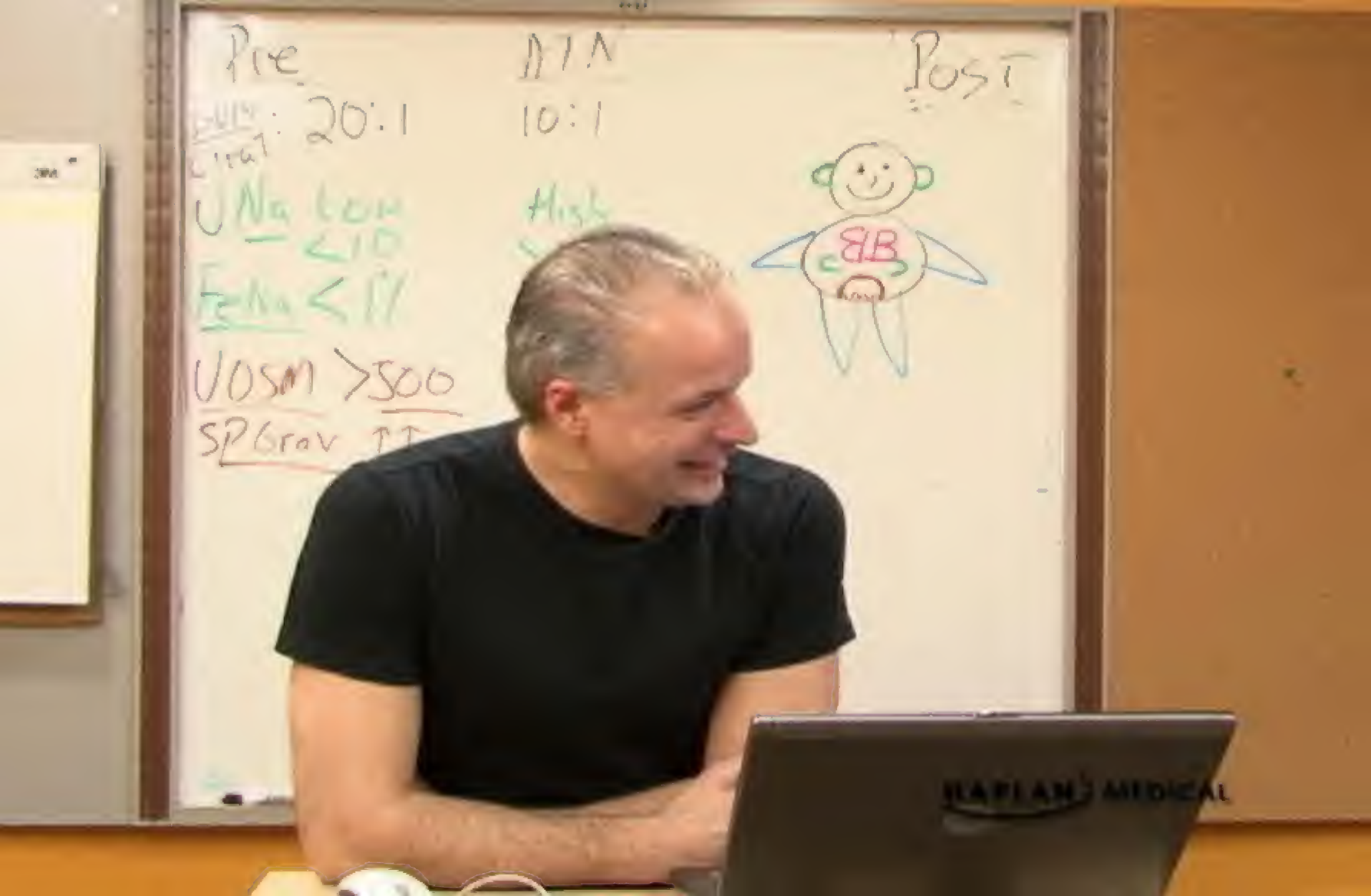
- Overall effect is decreasing the rate of progression to uremia and renal failure

Prerenal Failure—Hepatopulmonary Syndrome

- Similar to hepatorenal syndrome
- Renal failure is secondary to pulmonary disease
- Marked change in oxygen saturation with changes in position— *orthodeoxia*

Postrenal Azotemia—Etiology

- *Bilateral* obstruction to flow
  1. Bladder cancer
  2. Prostatic hypertrophy or cancer
  3. Bilateral ureteral disease
     - Retroperitoneal fibrosis
     - Neurogenic bladder
  4. Bilateral strictures


Pre
20:1
10:1
Post
UNa Low
<10
FeNa <1%
UOSM >500
SP Grav
BB
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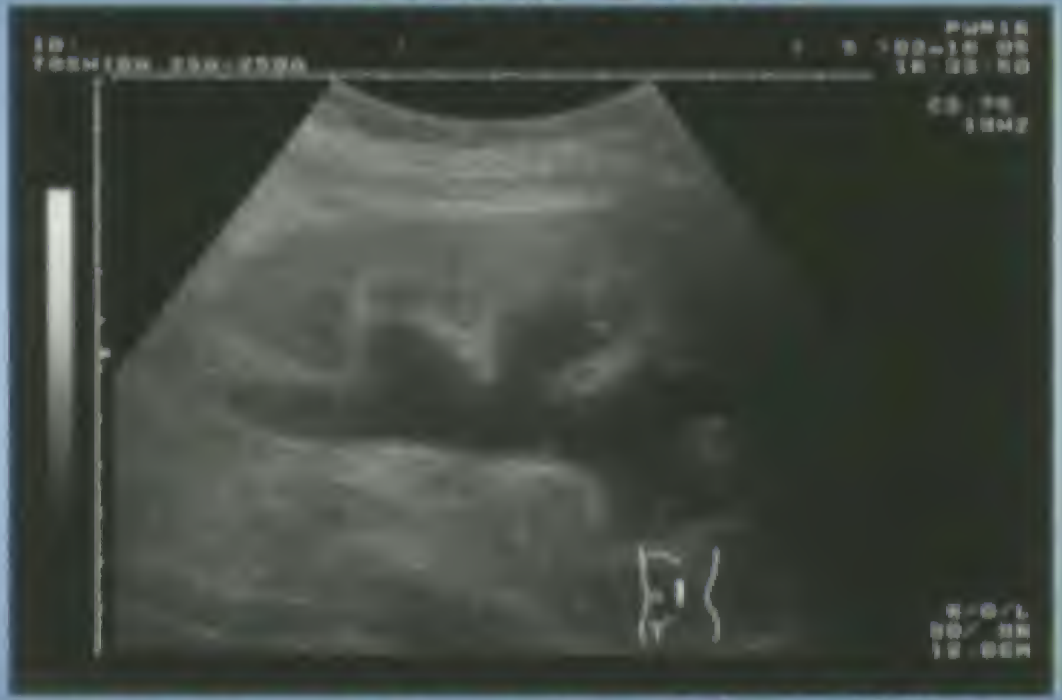
  3. Bilateral ureteral disease
     - Retroperitoneal fibrosis
     - Neurogenic bladder
  4. Bilateral strictures

Postrenal Azotemia— Etiology *(Cont'd)*

- Creatinine rises when *70-80% of renal function is lost*
- Initial elevation of BUN:Cr ratio of 20:1 (as with prerenal azotemia)
- ↓ fractional excretion of sodium
- ↓ urine sodium
- With chronic damage, BUN:Cr ratio decreases to 10:1 (as seen in ATN)

Hydronephrosis— Left-Sided Ureteral Stone



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Acute Renal Failure: Tubulointerstitial Disease

Acute Tubular Necrosis—Etiology

- Damage is tubular *or*
- Decreased perfusion *or*
- Decreased drainage *or*
- Toxic injury *or*
- May be a combination of the above factors

Acute Tubular Necrosis— Phases

1. Prodromal
   - Time between acute injury and the onset of renal failure
2. Oliguric (<400 ml/24 h) *or* anuric (<100ml/24 h)
3. Postoliguric
   - Diuretic phase when all fluids not previously excreted will leave the body in a vigorous polyuria

Acute Tubular Necrosis—Diagnosis

- BUN:Cr ratio of 10:1
- ↑ urine sodium (>40)
- ↑ fractional excretion of sodium (>1%)
- ↓ urine osmolality (<350)

Difference Between Prerenal and ATN

	PRERENAL	*ATN*
Urine osmolarity	>500	<350
Urine Na+	<20	>40
FeNa+	<1%	>1%
Urine sediment	Scant	Full (brownish pigmented granular casts, epithelial casts)

Acute Tubular Necrosis—Treatment

- Correct the underlying cause
- Hydration
- Supportive care

Allergic Interstitial Nephritis—Etiology

- 70% of cases due to adverse effect to medications
  1. Penicillins
  2. Cephalosporins
  3. Sulfa drugs
  4. Allopurinol
  5. Rifampin
  6. Quinolones

Allergic Interstitial Nephritis—Etiology *(Cont'd)*

- Infections (viruses, bacteria or fungi). Most common causes includes
  1. Leptospirosis
  2. *Legionella*
  3. CMV
  4. *Rickettsia*
  5. *Streptococci*
- Autoimmune disease
  1. SLE
  2. Sjögren syndrome
  3. Sarcoidosis
  4. Cryoglobulinemia

Allergic Interstitial Nephritis—Diagnosis

- Characteristic findings include
  1. *Rash*
  2. Fever
  3. Joint pain
  4. *Eosinophilia*
  5. *Increased serum IgE*
- Best initial test— urinalysis
  1. *Eosinophiluria (Wright or Giemsa stain)*
  2. Hematuria
  3. Proteinuria (<2 g/24 hrs)

Allergic Interstitial Nephritis—Diagnosis *(Cont'd)*

- Most accurate test
  1. Biopsy
  2. Rarely performed
- Treatment
  1. Stop the offending agent
  2. +/– corticosteroids

Pigments—Etiology

- Myoglobinuria (rhabdomyolysis)
  1. Severe crush injury
  2. Seizures
  3. Severe exertion
  4. Less common: hypokalemia, hypophosphatemia, or meds (statins)
- Hemoglobinuria
  1. ABO incompatibility

Pigments—Etiology

- Directly toxic to renal tubules
- Precipitate in renal tubules
- Damage is directly proportional to duration of contact
- Worsened with dehydration

Pigments— Diagnosis

- Severe crush injury or seizure (potentially life threatening)
  1. EKG or serum potassium → peaked T-waves → IV calcium gluconate or calcium chloride
- Not potentially life threatening
  1. Urinalysis → Dipstick + for RBCs but none visualized on microscopy
- Confirmatory test
  1. Serum CPK → 10,000 – 100,000 (normal <500)
- Other findings: rapidly increased Cr, metabolic acidosis, decreased serum bicarb, hyperphosphatemia

Pigments— Management

- EKG abnormalities: IV calcium gluconate or IV calcium chloride stat
- Aggressive hydration
- Mannitol
- +/– Alkalization of the urine

Proteins— In Summary

- Associated with multiple myeloma
- Bence-Jones proteins cause tubular damage
- Also cause nephritic syndrome

Crystals— Etiology

- Oxalate
  1. Most common cause is ethylene glycol overdose
  2. Intoxicated person with increased anion gap metabolic acidosis
  3. Renal insufficiency
  4. Diagnosis is confirmed with envelope-shaped crystals seen on UA
  5. Treatment includes IV ethanol or fomepizole and dialysis
  6. Other causes in includes Crohn's disease which results in chronic hyperoxaluria and stones

Crystals— Etiology

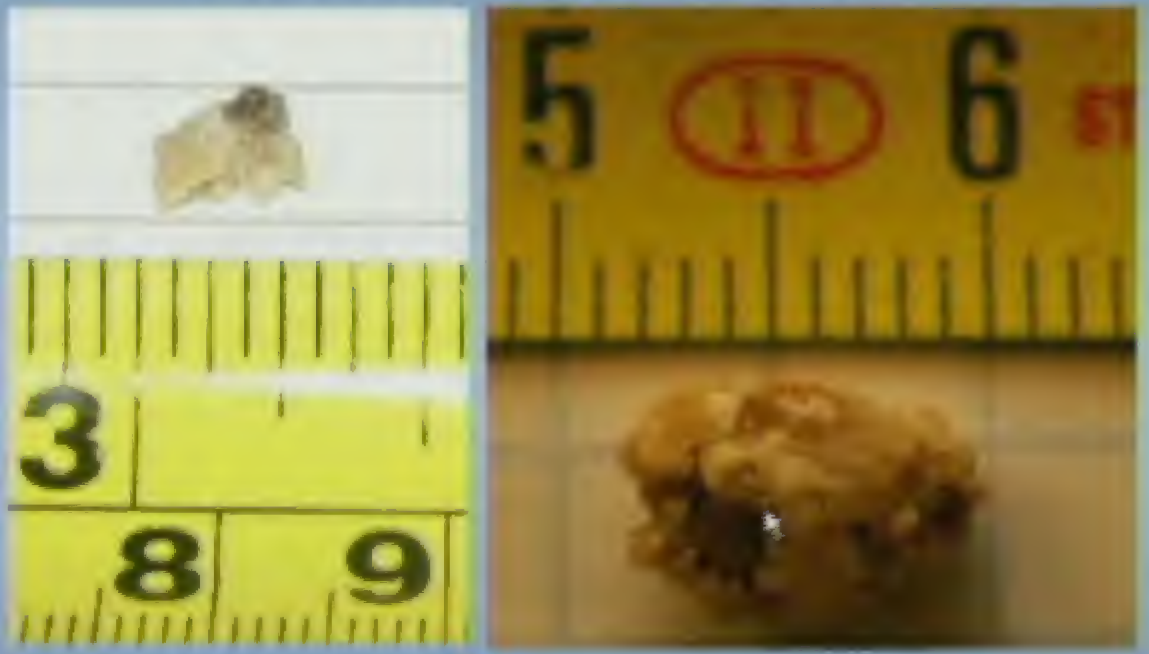
- Urate
  1. Most common cause is tumor lysis syndrome (acute) and gout (chronic)
  2. All patients undergoing chemo must receive vigorous hydration and allopurinol
  3. Stones and crystals precipitate in acidic urine
  4. Diagnosis by finding crystals in the urine

Hypercalcemia

- Results in:
  1. Stones
  2. Distal renal tubular acidosis
  3. Nephrogenic diabetes insipidus
- Most common cause:
  - Primary hyperparathyroidism

    Surgical resection only done with *symptomatic disease*

5-mm Renal Stones—Passed Naturally without Intervention



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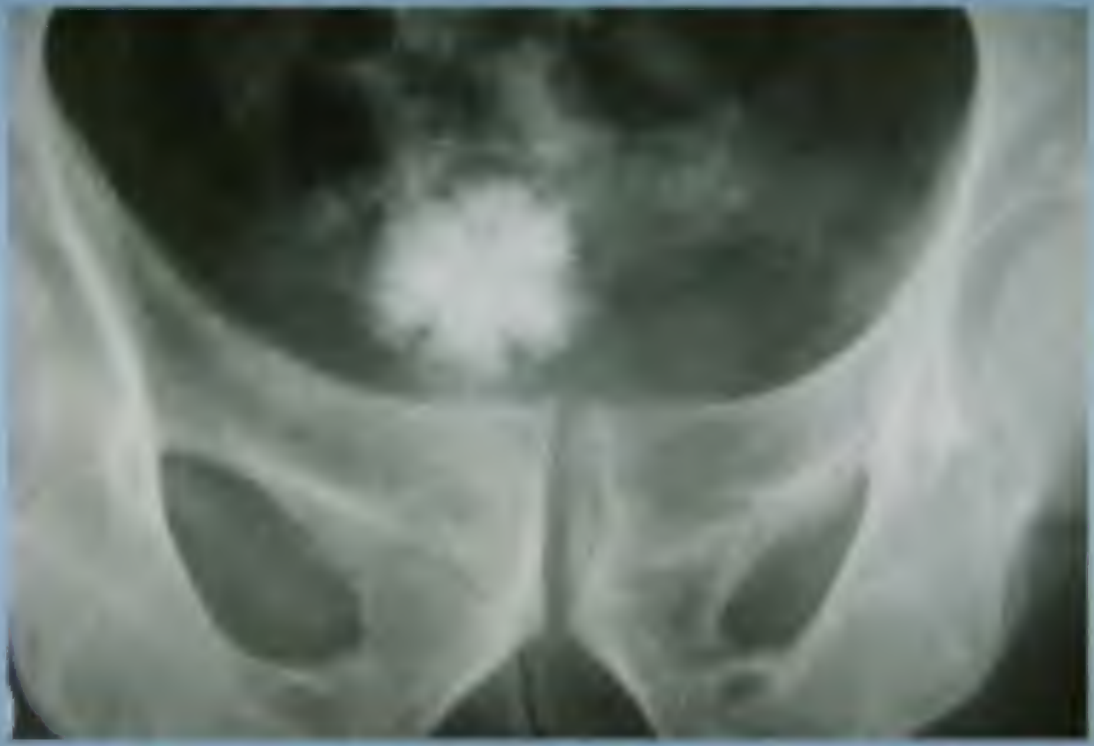
Large Stellate Urolith



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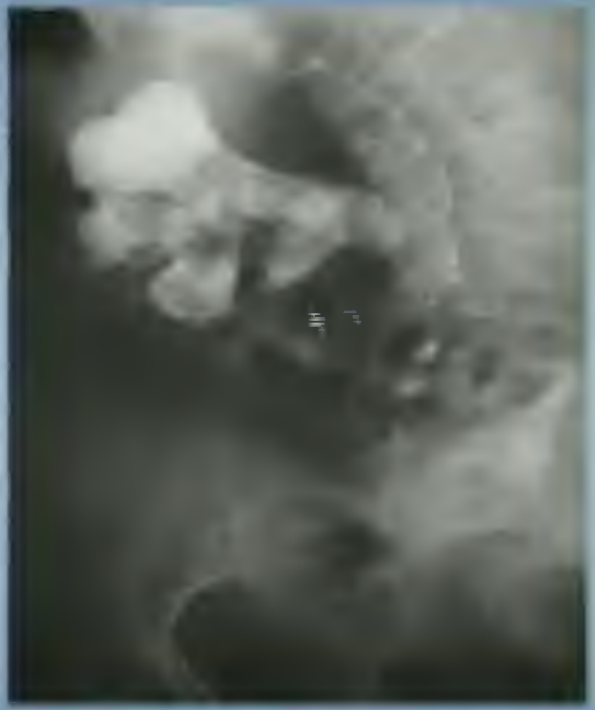
Staghorn Calculus and Scoliosis



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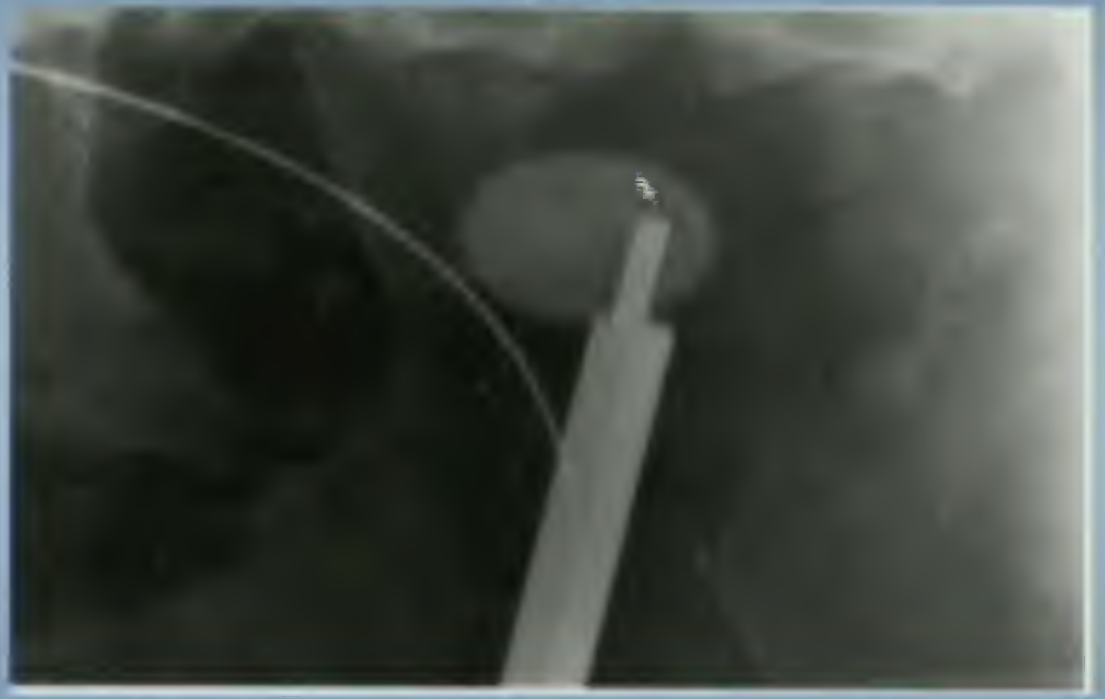
Ultrasound Ablation of a Large Renal Stone



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Toxins— Etiology

- Most common toxins implicated:
  1. NSAIDs
  2. Aminoglycosides
  3. Cephalosporins
  4. Contrast agents
  5. Amphotericin B
  6. Chemotherapy
  7. Radiation
  8. Heavy metals
  9. Cyclosporine

Toxins— Etiology

- Aminoglycosides: exacerbated by hypokalemia and hypomagnesemia, toxicity associated with trough level
- Amphotericin B: days-weeks (cumulative) of use results in ↑ Cr, ↓ K, ↓ HCO_3
- Atheroembolic disease: renal failure several days after procedure. *Eosinophilia*, low complement, bluish discoloration of the extremities, livedo reticularis
- Contrast agents: 12–24 hours later. Poor function of renal parenchyma *prior to the procedure increases risk.*

Analgesic Nephropathy— NSAIDs

- Several mechanisms are involved:
  1. Interstitial nephritis
  2. Direct toxicity
  3. Papillary necrosis
  4. Inhibition of prostaglandins
  5. Membranous glomerulonephritis
- Occurs in those with significant impairment: HTN, diabetes, and the elderly
- History of NSAID use with ↑ in BUN and Cr
- No specific treatment

Papillary Necrosis

- Causes
  1. Sickle cell disease
  2. Diabetes
  3. Urinary obstruction
  4. Chronic pyelonephritis
  5. NSAIDs
- Presentation: Acute onset of flank pain, hematuria, pyuria, negative urine cultures and fever
- Most accurate test: CT scan— "bumpy" contours of the renal pelvis
- No specific treatment

Preventing Contrast-Induced Renal Failure

- **Vigorous hydration**
- 1–2 L of 0.9% NS over 12 hours prior to procedure
- Bicarbonate and N-acetylcysteine have some protective effect

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Glomerulonephritis: Nephritic Syndrome

Glomerulonephritis— An Overview

- Inflammation of the glomeruli due to
  1. Autoimmune events
  2. Circulating antibodies
  3. Vasculitis
- Edema → salt and water retention → hypertension
- Hematuria with dysmorphic RBCs and RBC casts
- Proteinuria <2 grams/24 hours
- Fractional excretion of Na <1%
- Most important diagnostic test: **renal biopsy**

Vascular Disease	*Glomerular Disease*
Wegener's granulomatosis	Goodpasture syndrome
Churg-Strauss syndrome	Postinfectious glomerulonephritis
Henoch-Schönlein Purpura	IgA Nephropathy (Berger disease)
Polyarteritis Nodosa	SLE
TTP	Idiopathic rapidly progressive glomerulonephritis
HUS	Alport syndrome
Cryoglobinemia	Diabetes and HTN
	Amyloid

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Glomerulonephritis: Nephrotic Syndrome

Nephrotic Syndrome

- ***Proteinuria >3.5 grams per day***
- ***Hyperlipidemia*** → unclear etiology
- ***Edema*** → secondary to increased salt and water retention and decreased oncotic pressure
- ***Low serum albumin*** → secondary to protein loss

Severe Generalized Edema

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Nephrotic Syndrome *(Cont'd)*

- Associated with systemic illness
  1. Diabetes
  2. Hypertension
  3. Multiple myeloma
- Nephritic syndrome may progress to nephrotic syndrome
- Glomerular basement membrane loses its negative potential → protein loss
- Also associated with **hyperlipidemia** which gives the form of a **Maltese cross in the urine**

Maltese Cross

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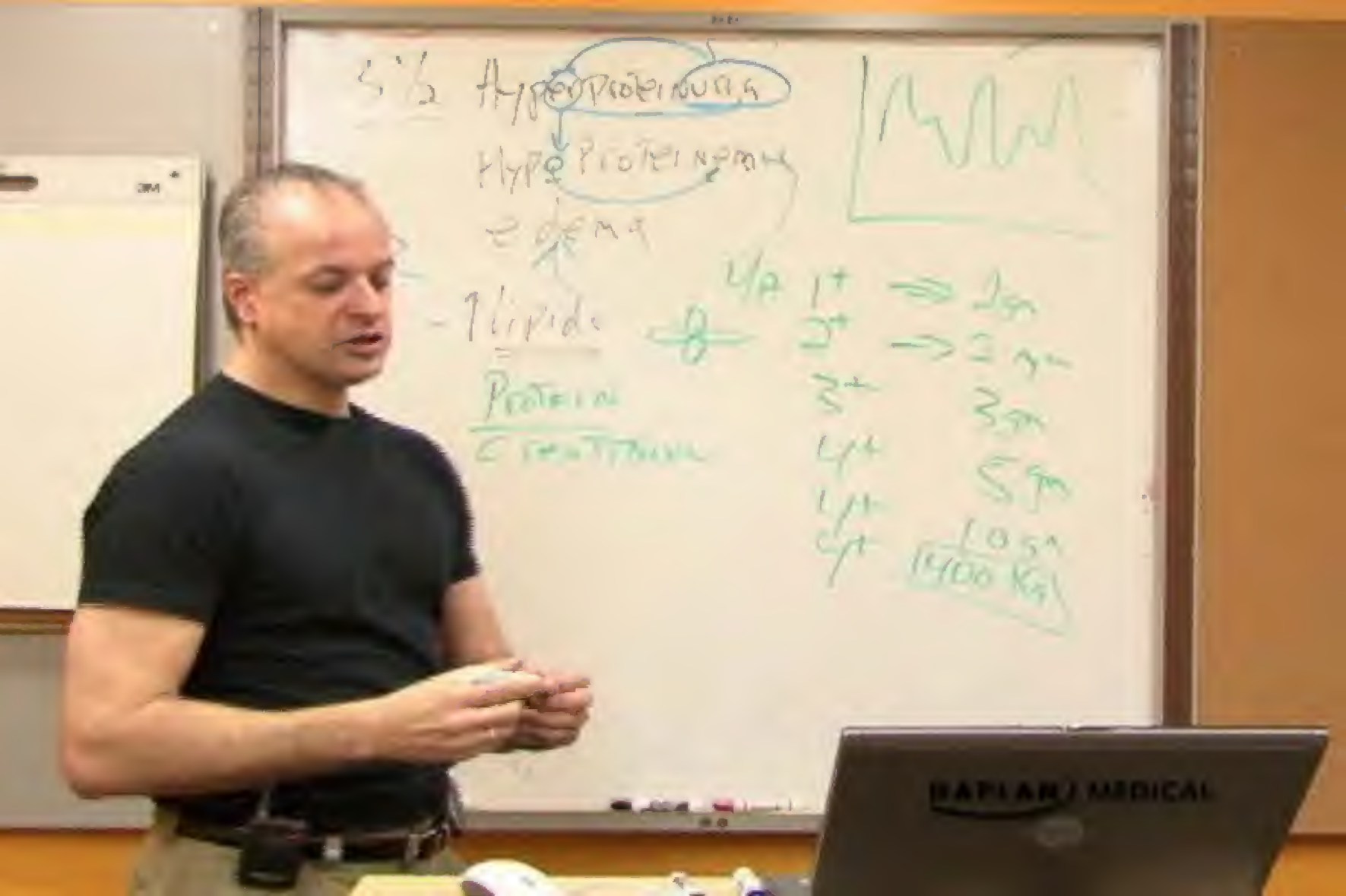
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Nephrotic Syndrome *(Cont'd)*

- Urinary loss of anticoagulant proteins, i.e., protein C, protein S, and antithrombin → **hypercoagulable state**
- Urinary loss of transport proteins → **Iron, copper and zinc deficiency**

Nephrotic Syndrome— Diagnosis

- Urinalysis shows >3.5 grams/24 hours
  1. Cumbersome test
  2. Most often used: **single spot urine for albumin and creatinine**
- Most accurate test to determine etiology is a **renal biopsy**

Nephrotic Syndrome— Diagnosis

- Urinalysis shows >3.5 grams/24 hours
  1. Cumbersome test
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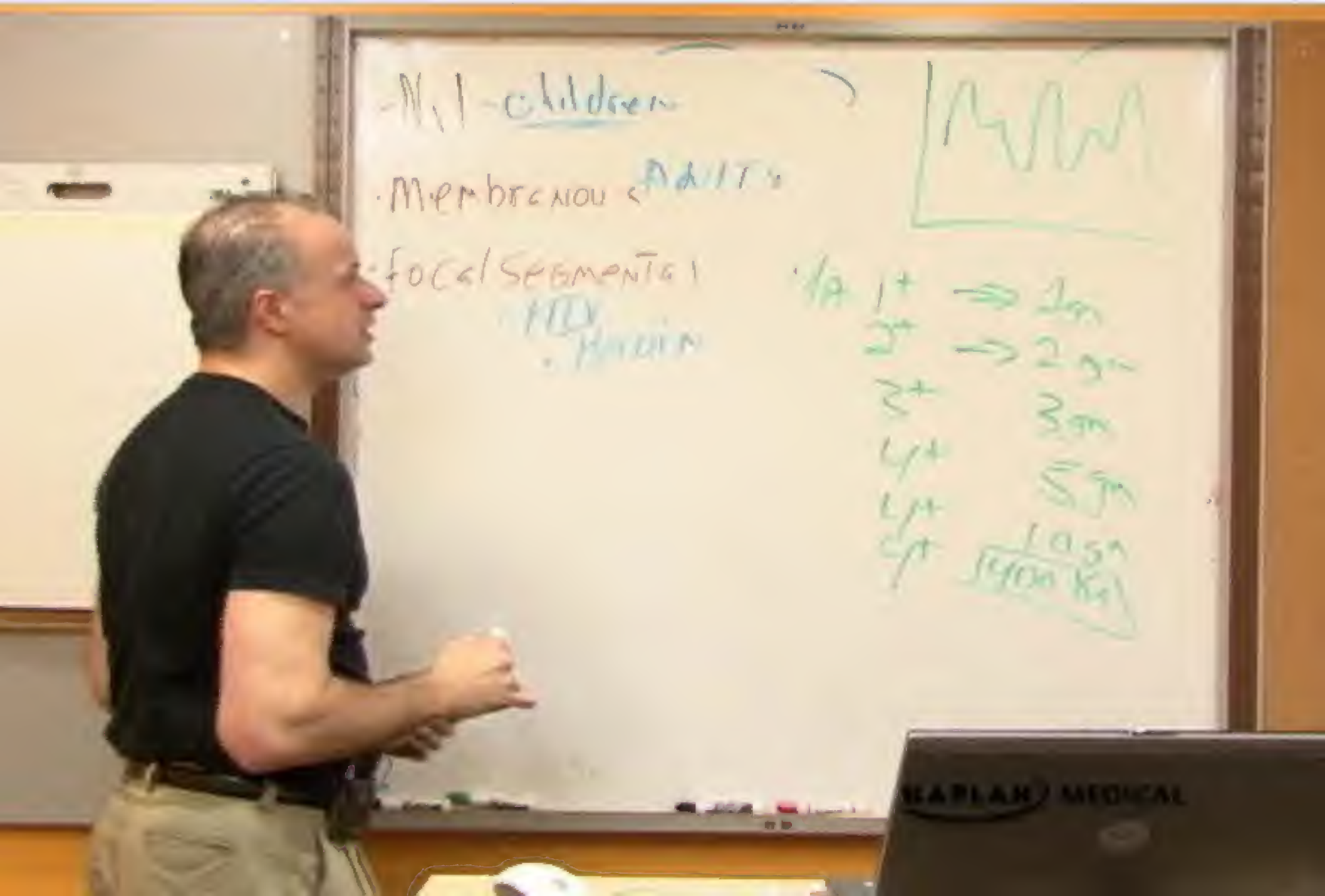
Nephrotic Syndrome— Treatment

- Control underlying disease
- **Steroids in all idiopathic primary renal disease**
  1. Membranous type
  2. Nil lesion
  3. Membranoproliferative type
  4. Mesangial type
  5. Focal segmental disease
- **Steroids ineffective?**
  1. **Add cyclophosphamide or mycophenolate** (maybe azathioprine)
- **ACE inhibitors or ARBs** used in all patients but does not reverse disease


-M.I - children
· Membranou < ADULT
· focal segmental
FSGS
· Minimin
1+ ⇒ 1gm
2+ ⇒ 2 gm
3+ 3gm
4+ 5gm
1.5gm
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Membranous Glomerulonephritis

- Most common idiopathic disease in adults
- Also associated with cancer, infections, hepatitis, lupus, penicillamine, gold salts, and NSAIDs

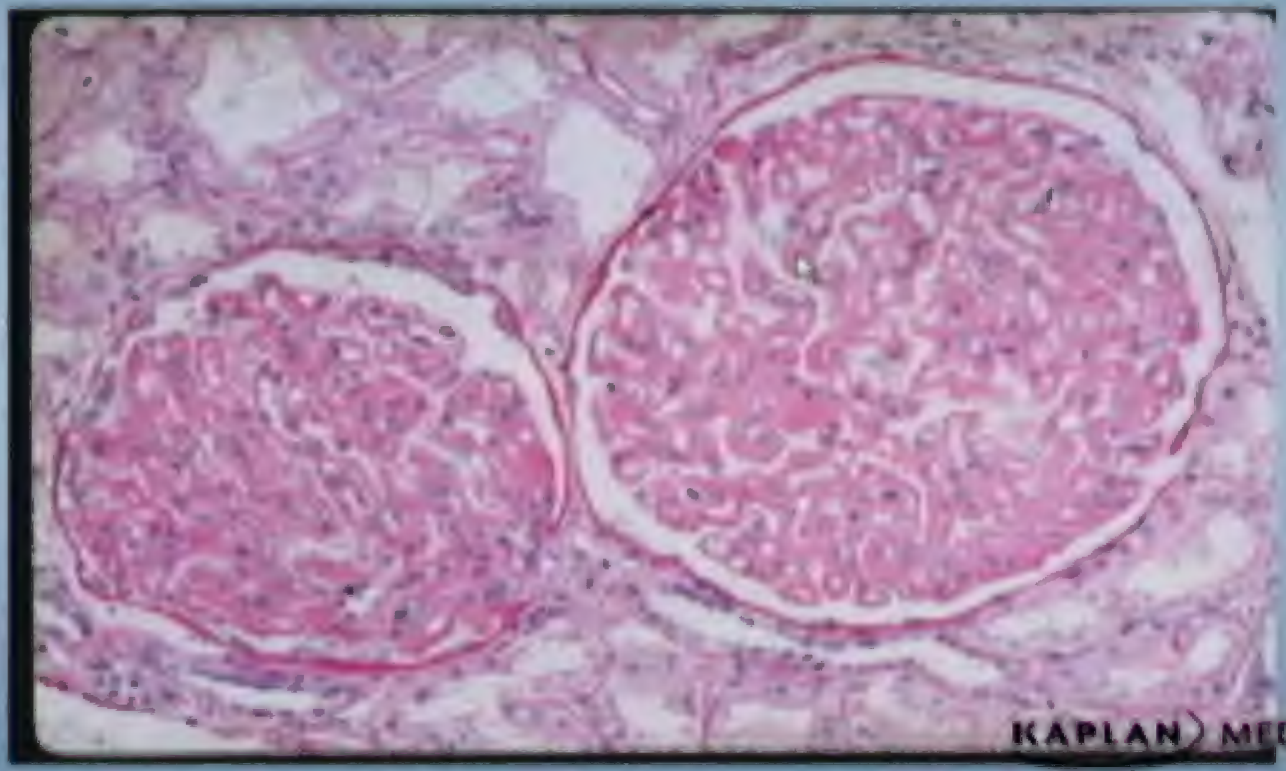
Nil lesion—Minimal Change Disease

- Most common idiopathic cause in children
- NSAIDs
- Light microscopy is **normal** electron microscopy shows **fusion of foot processes**
- Responds very well to **steroids**

Membranoproliferative Glomerulonephritis

- Associated with chronic hepatitis and low serum complement
- Positive cryoglobulins?
  1. Interferon + ribavirin
- Dipyrimadole and aspirin are also used

Membranoproliferative Glomerulonephritis



Focal Segmental Glomerulonephritis

- Highly associated with **heroin and HIV!**
- Poor response to steroids
- Rapid progression to end-stage renal diease

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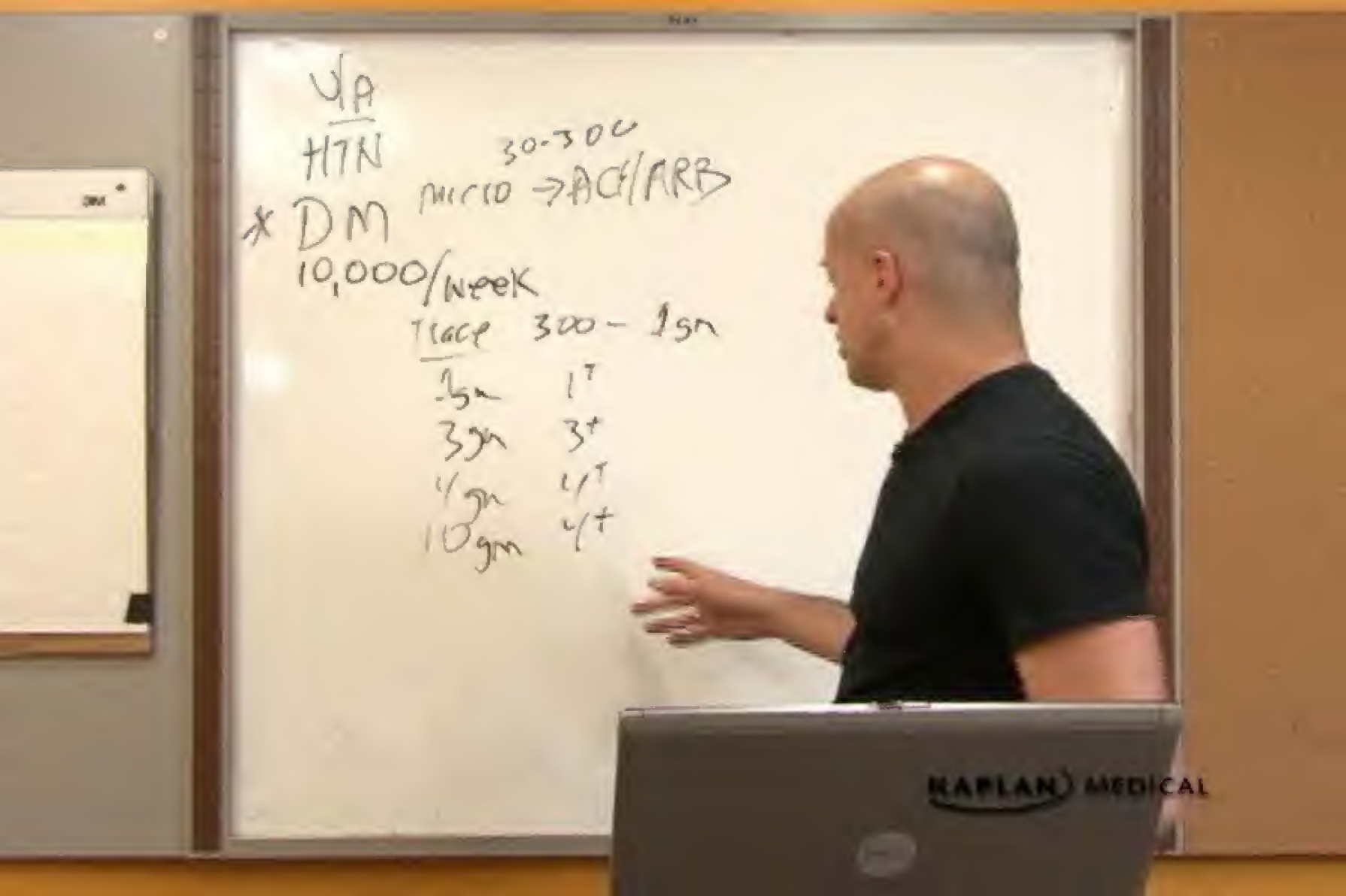
Diagnostic Testing in Renal Disease

Diagnostic Testing in Renal Disease

- *Urinalysis*
- No recommendations for routine testing in the general population
- Screening in diabetes in HTN

Diagnostic Testing in Renal Disease

- Proteinuria
  - From either glomerular or tubal disease
  - Microalbuminuria → 30–300 mg/24 h
  - Mild proteinuria (<1gm/day) in up to 10% of the population, usually resolves spontaneously
  - Proteinuria secondary to **stress** → fever, CHF, extreme exercise
  - **Orthostatic proteinuria → prolonged standing → Benign**
    - Diagnosed by splitting 24 urine → First 8 hours, no protein; next 8 hours, positive protein


UA
HTN
30-300
micro → ACE/ARB
* DM
10,000/week
Trace 300 - 1gm
1gm 1+
3gm 3+
4gm 4+
10gm 4+
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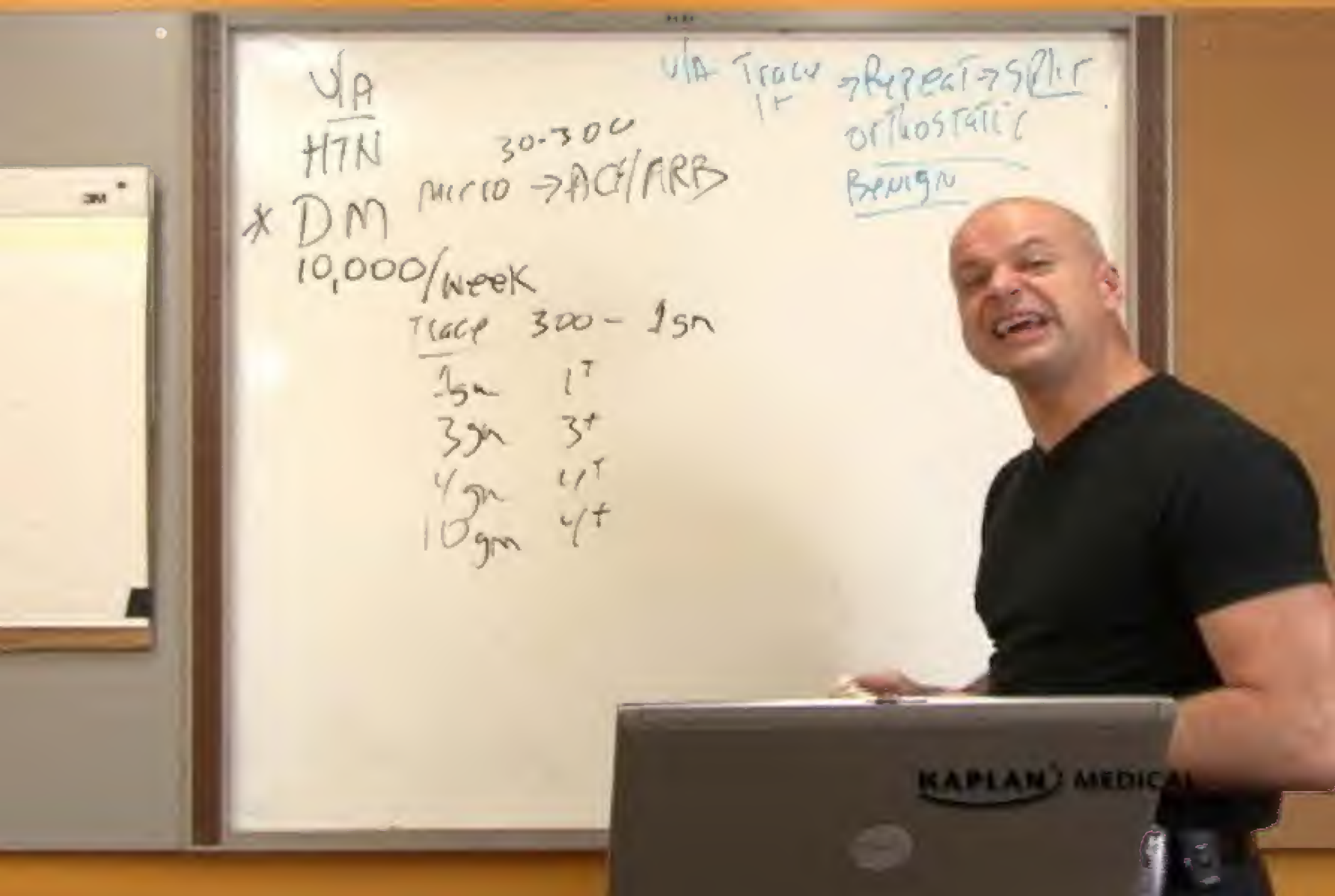
UA
HTN
* DM
10,000/week
30-300
micro → ACE/ARB
UA Trace 1+ → Repeat → Sulfur
orthostatic
Benign
Trace 300 - 1gm
1gm 1+
3gm 3+
4gm 4+
10gm 4+
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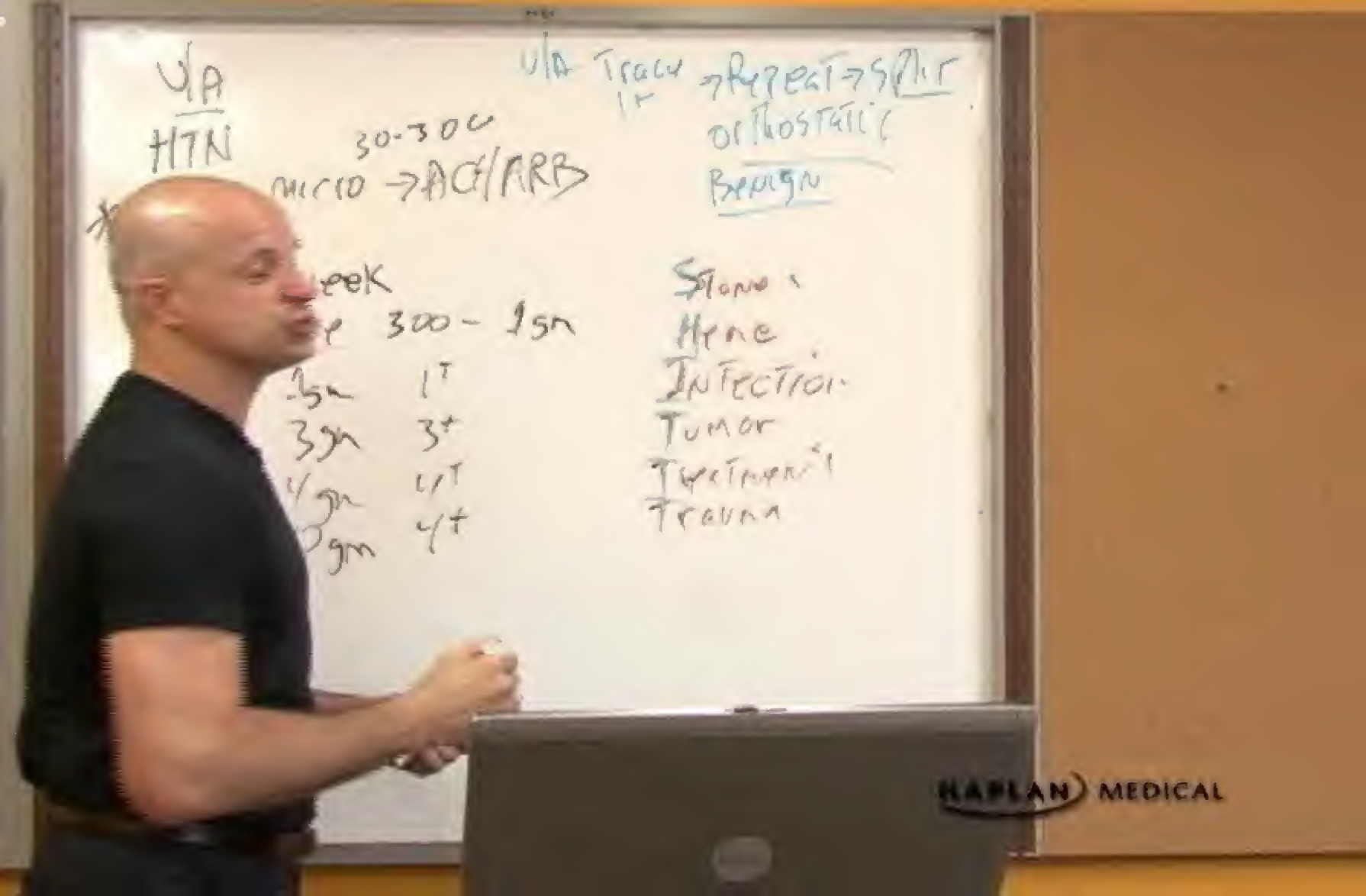
Diagnostic Testing in Renal Disease

- Hematuria
  - Bladder → intact RBCs
  - Kidney → dysmorphic RBCs
  - Etiology includes
    - Stones
    - Cancer
    - Bleeding disorders
    - Trauma
    - Cyclophosphamide


UA
HTN
30-300
micro → ACE/ARB
UA Trace 1+ → Repeat → Spin
or Prostatic
Benign
eek
300 - 1gm
1gm 1+
3gm 3+
4gm 4+
Stone
Heme
Infection
Tumor
Trauma
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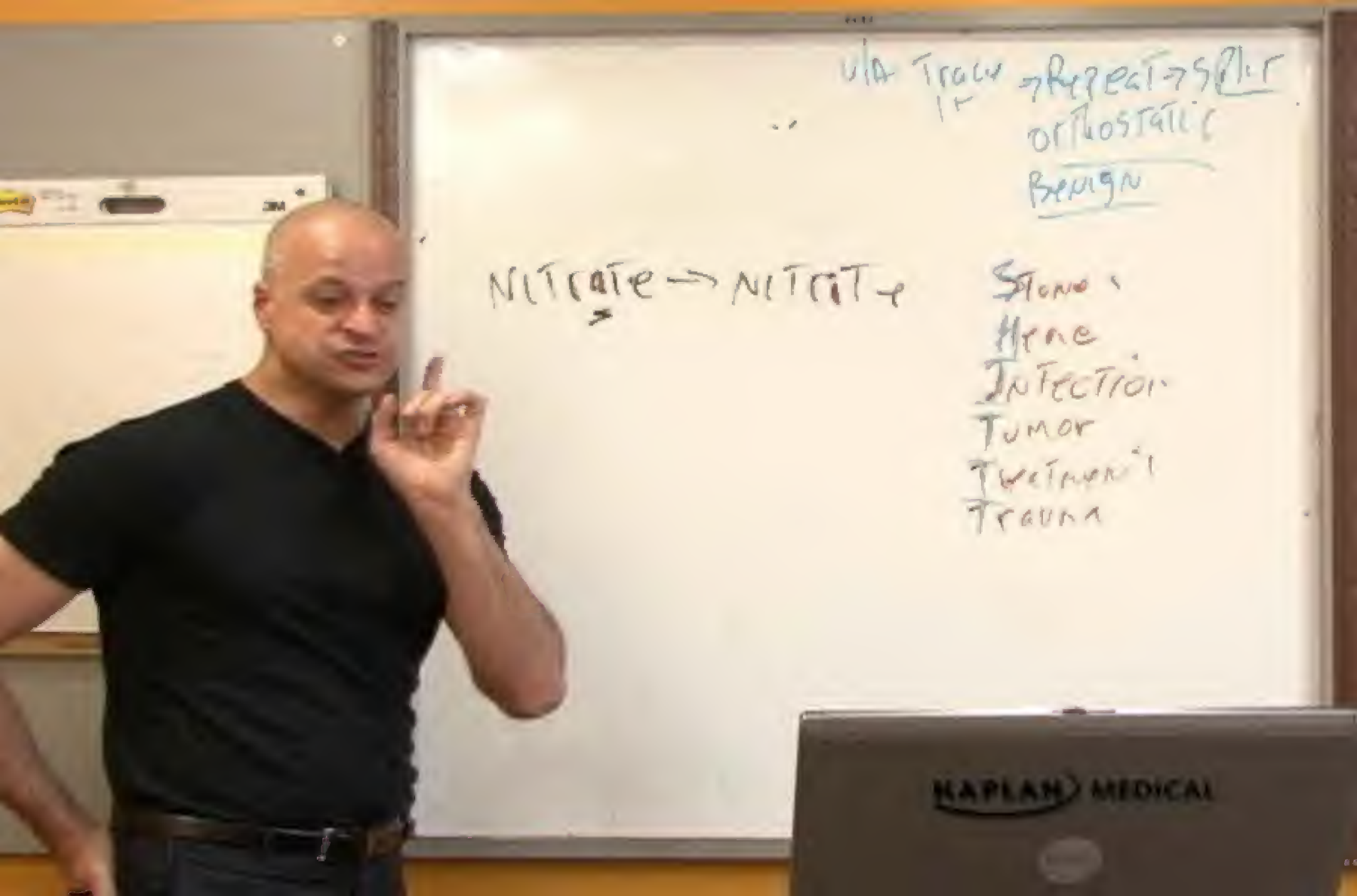
Diagnostic Testing in Renal Disease

- Nitrites on dipstick
  - Bacteria reduce nitrate → nitrite
  - Marker of infection
- Bacteriuria
  - Isolated finding little significance
    - **Except in pregnant women**
    - Routine screening recommended
    - Treatment indicated if positive
    - 30% of pregnant women with bacteruria progress to pyelonephritis


UA Trauma
Repeat
Orthostatic
Benign
Nitrate → Nitrite
Stone
Urine
Infection
Tumor
Treatment
Trauma
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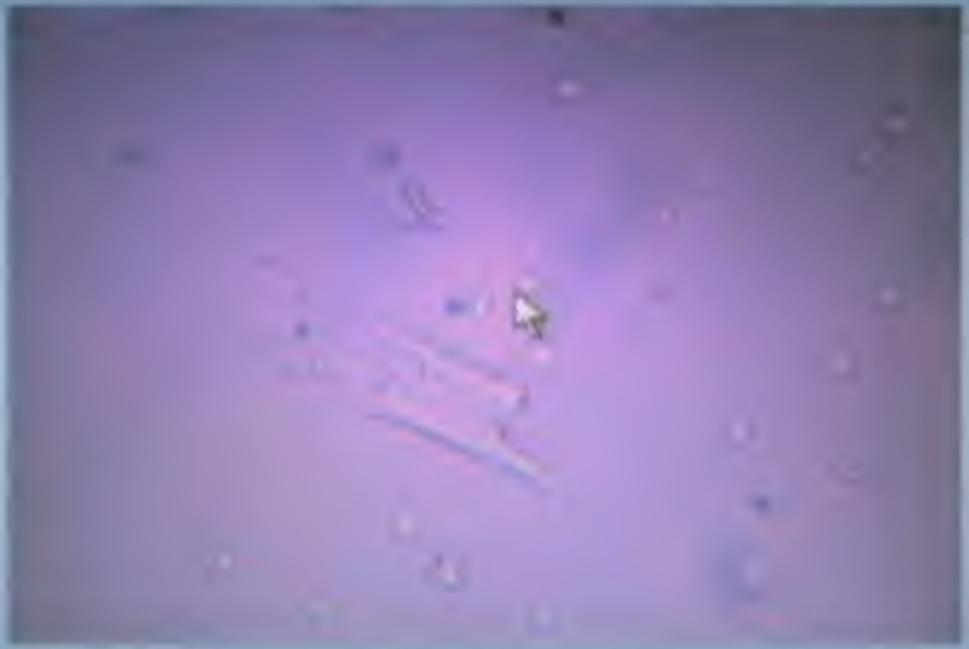
Significance of Urinary Casts

Hyaline	Dehydration. Accumulation of normal tubular protein. Does not always implicate disease
Red cell	Glomerulonephritis
Broad, waxy	Chronic renal failure
Granular	Also called "dirty" or "muddy" Associated with ATN. Accumulated epithelial cells
White cell	Pyelonephritis, interstitial nephritis

Hyaline Urinary Cast— Dehydration



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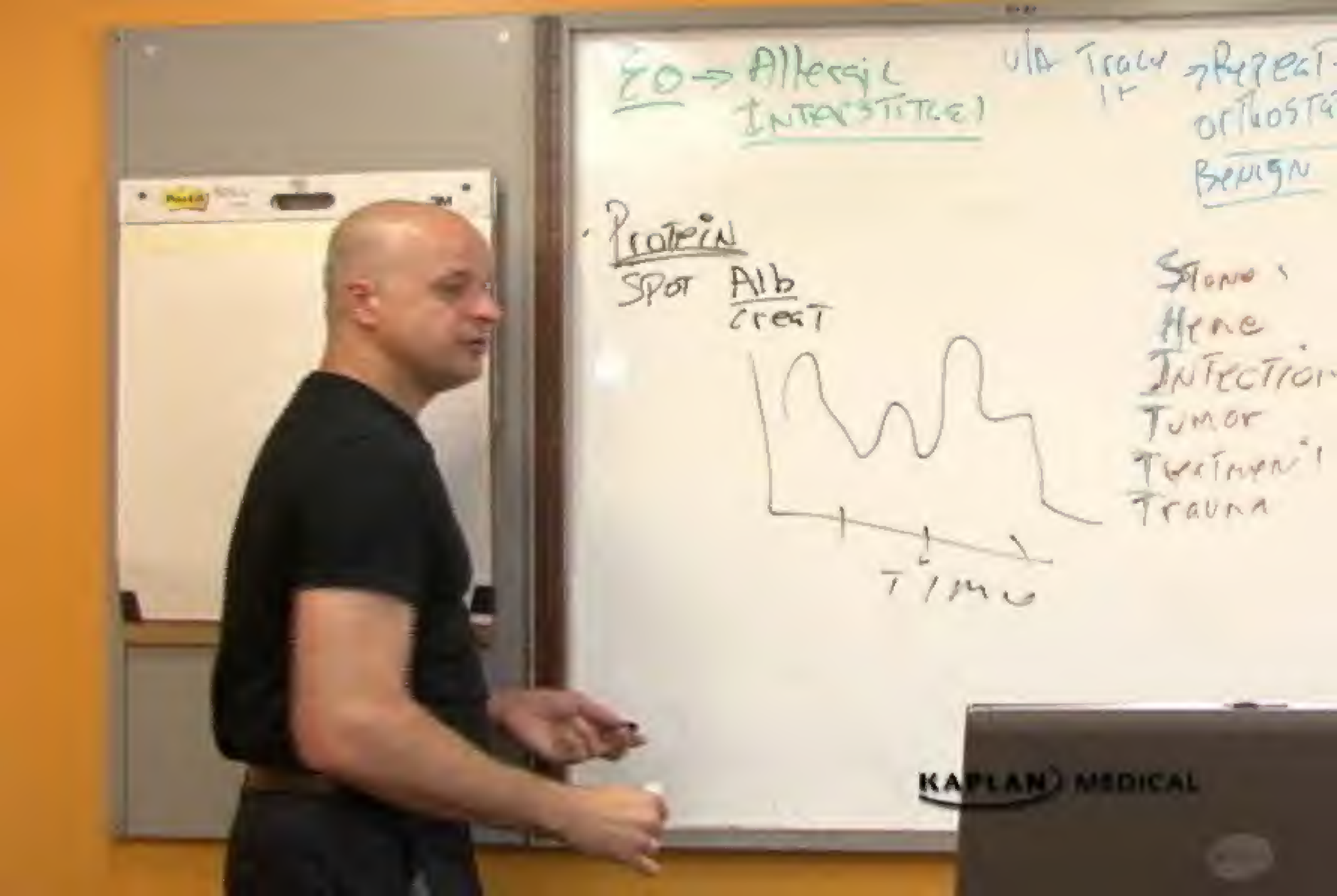
EO → Allergic
INTERSTITIAL
UA Trace
Protein
Spot Alb
Creat
TIME
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End Stage Renal Disease/ Dialysis

- Overview
  1. Most common causes are diabetes and hypertension
  2. Glomerulonephritis
  3. Cystic disease
  4. Interstitial nephritis

End Stage Renal Disease/ Dialysis

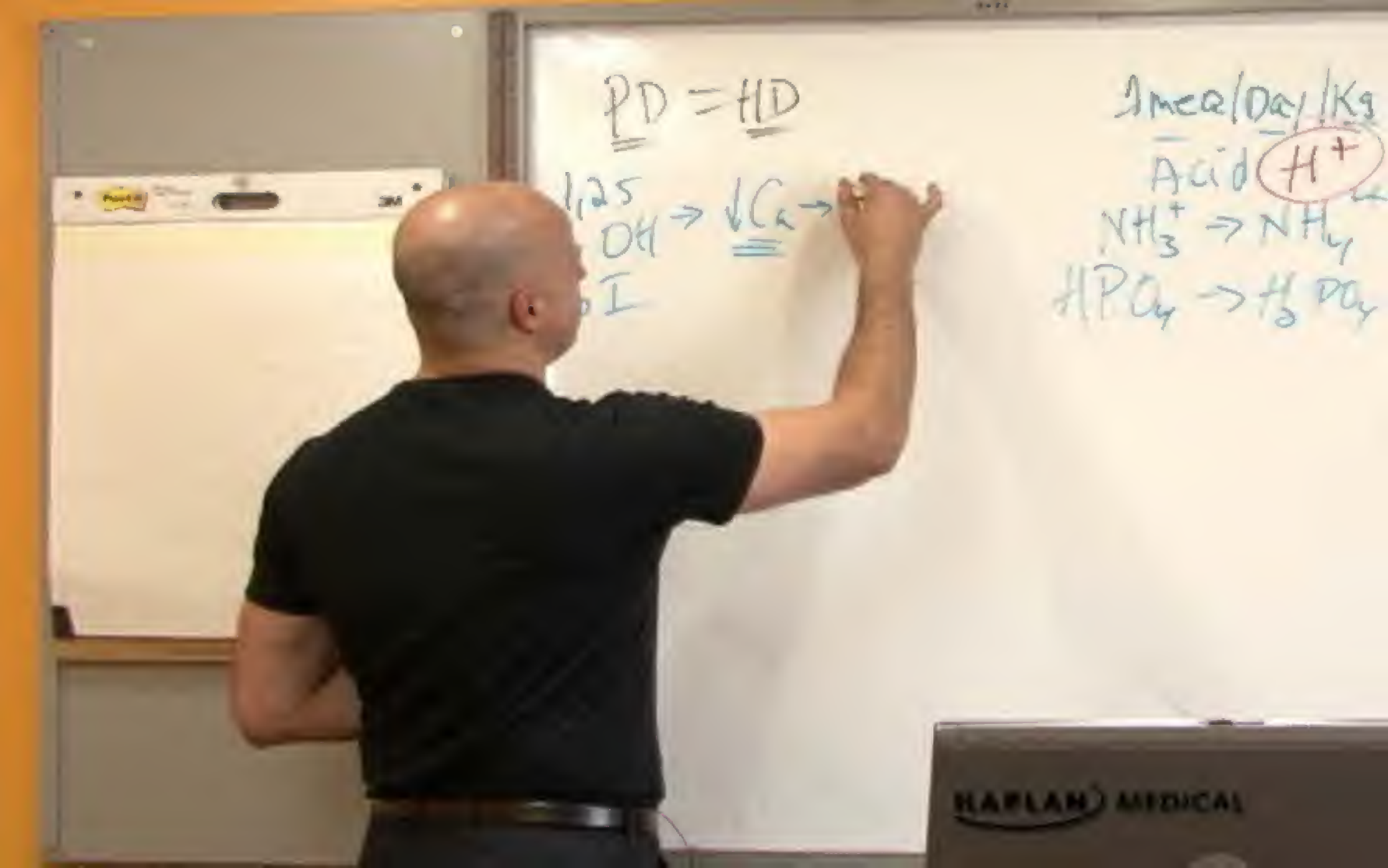
- Indications for dialysis → life-threatening abnormalities
  1. Fluid overload
  2. Severe acidosis
  3. Pericarditis
  4. Encephalopathy and severe neurologic impairment
  5. Severe hyperkalemia

End Stage Renal Disease/ Dialysis

- Hemodialysis used in 85% of patients
- Peritoneal dialysis in 15%
  1. Most common complication is **peritonitis**

End Stage Renal Disease/ Dialysis

- Complications
  - Anemia → loss of erythropoietin
  - Hypocalcemia/ hyperphosphatemia → loss of 1,25 dihydroxy-vitamin D
    - High phosphate: calcium carbonate, calcium acetate, Sevelamer, lanthanum, Cinacalcet
    - Do not used aluminum-based binders!!
  - Osteodystrophy (osteitis fibrosa cystica) → loss of 1,25 dihydroxy-vitamin D


PD = HD
1,25
OH → VCa →
I
1meq/Da/Kg
Acid H+
NH3+ → NH4
HPO4 → H2PO4
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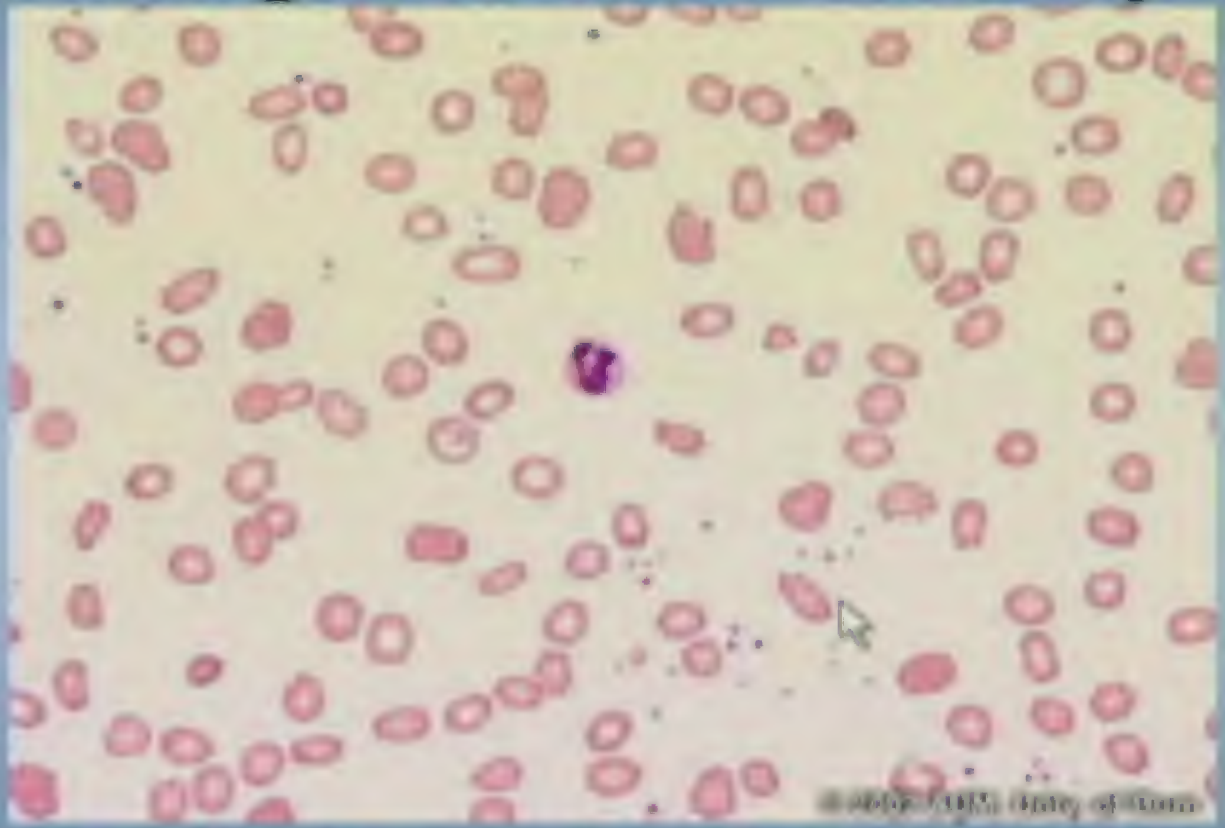
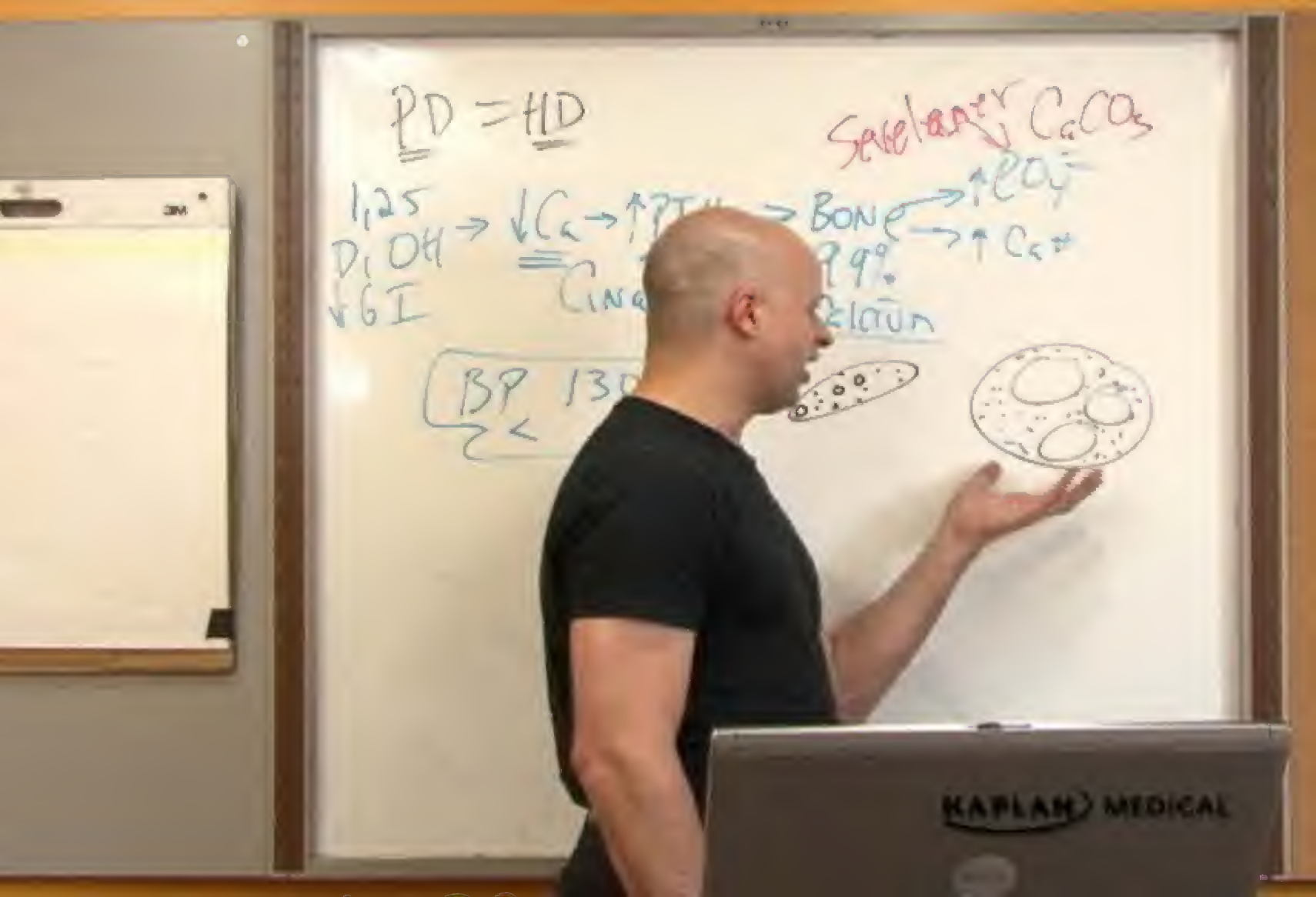
End Stage Renal Disease/ Dialysis



Peripheral smear of a patient with ESRD

End Stage Renal Disease/ Dialysis

- Complications *(Cont'd)*
  - Hypermagnesemia → decreased excretion
  - Hypertension and accelerated arthrosclerosis → unclear etiology, **most common cause of death**, BP goal **<130/80**
  - Infection → uremia impairs WBC function
  - Bleeding → platelet dysfunction, treat with **desmopressin**
  - Dietary treatment → restrict sodium, potassium, magnesium, phosphate and protein


PD = HD
1,25
D, OH
↓GI
BP 13
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PD = HD

Skeletal $CaCO_3$

$\downarrow Ca \rightarrow \uparrow PTH \rightarrow$ BONE $\rightarrow \uparrow PO_4$

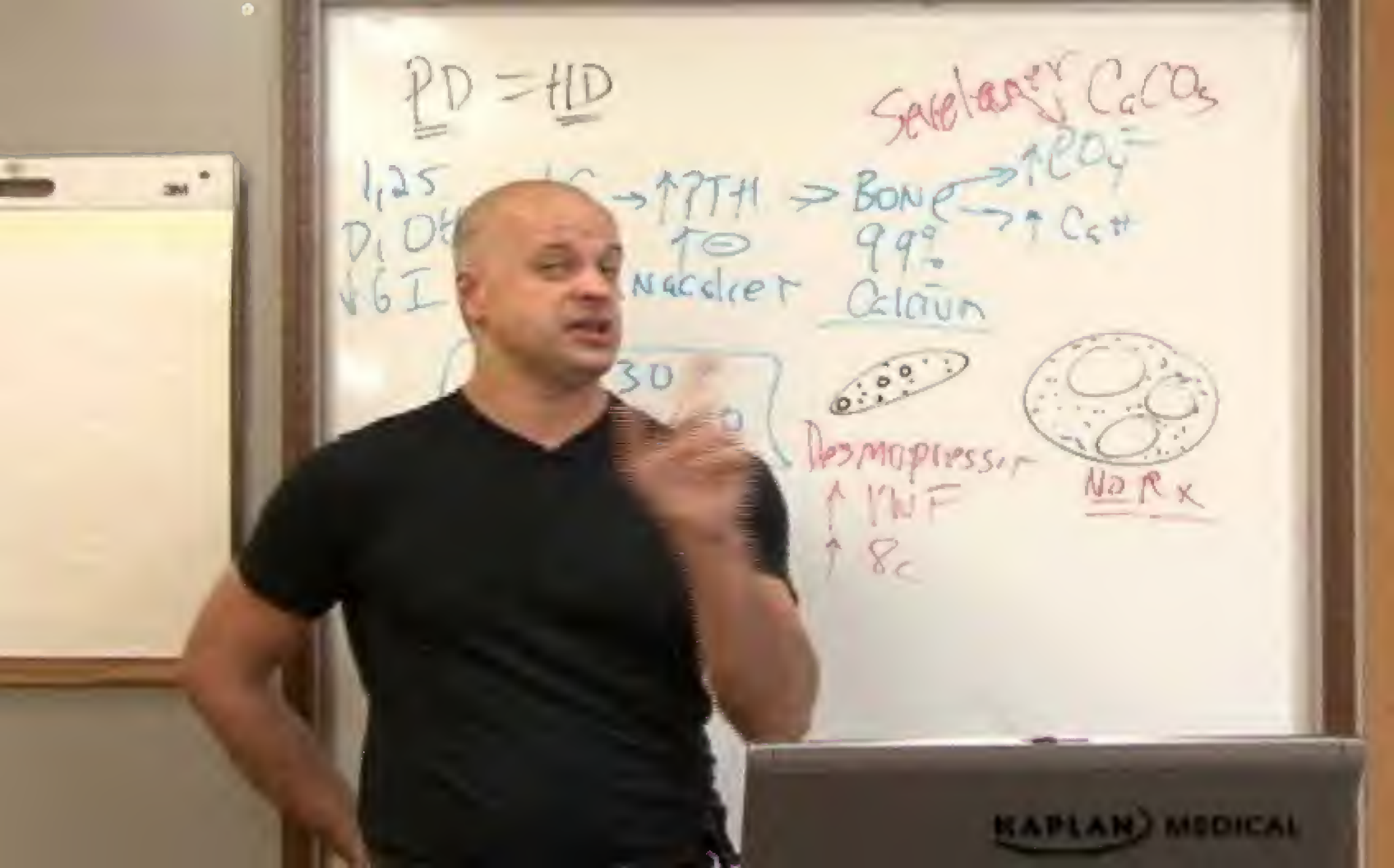
$\rightarrow \uparrow Ca^{++}$

99% Calcium

Cinacalcet

BP < 130/80

No Rx


PD = HD
Skeleton
$CaCO_3$
PO_4^{3-}
1,25
↑PTH
BONE
99%
Calcium
NaCl
Vasopressin
↑ TNF
↑ 8c
NaRx
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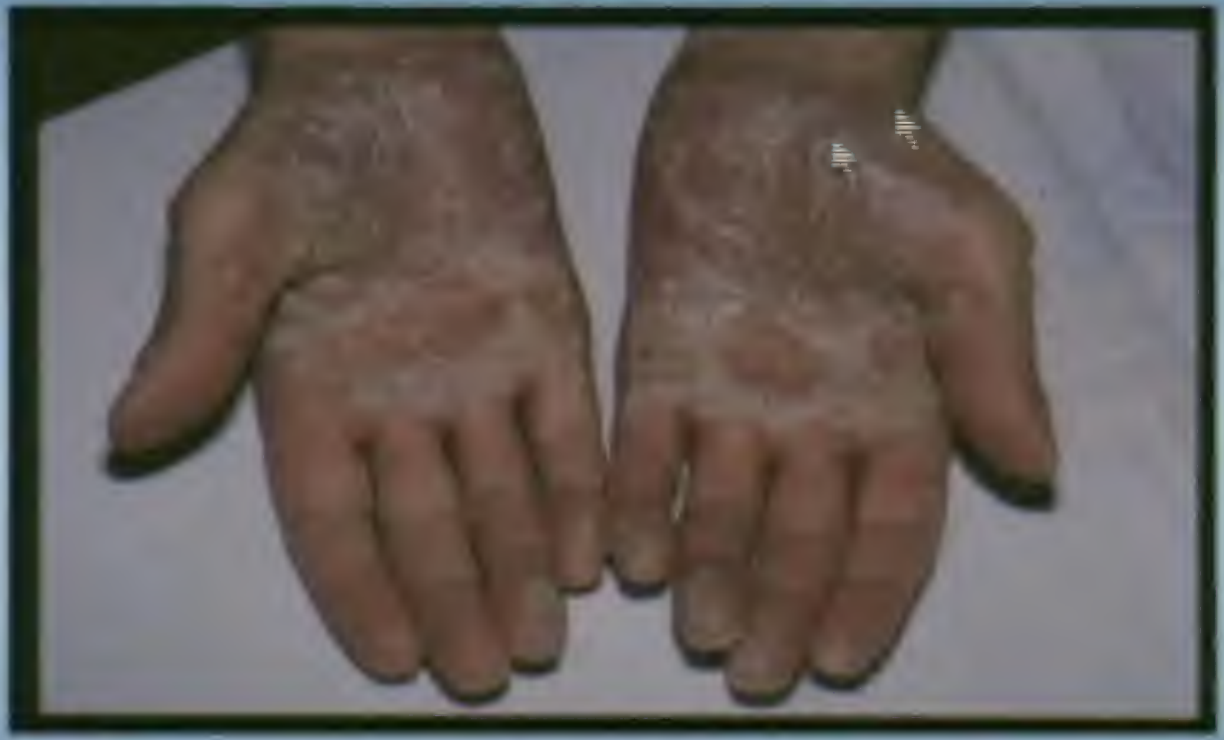
Survival Statistics

Live, related donor	95% at one year, 72% at 5 years
Cadaver donor	88% at one year, 58% at 5 years
Dialysis alone	30–40% at 5 years
Diabetics on dialysis alone	20% at 5 years

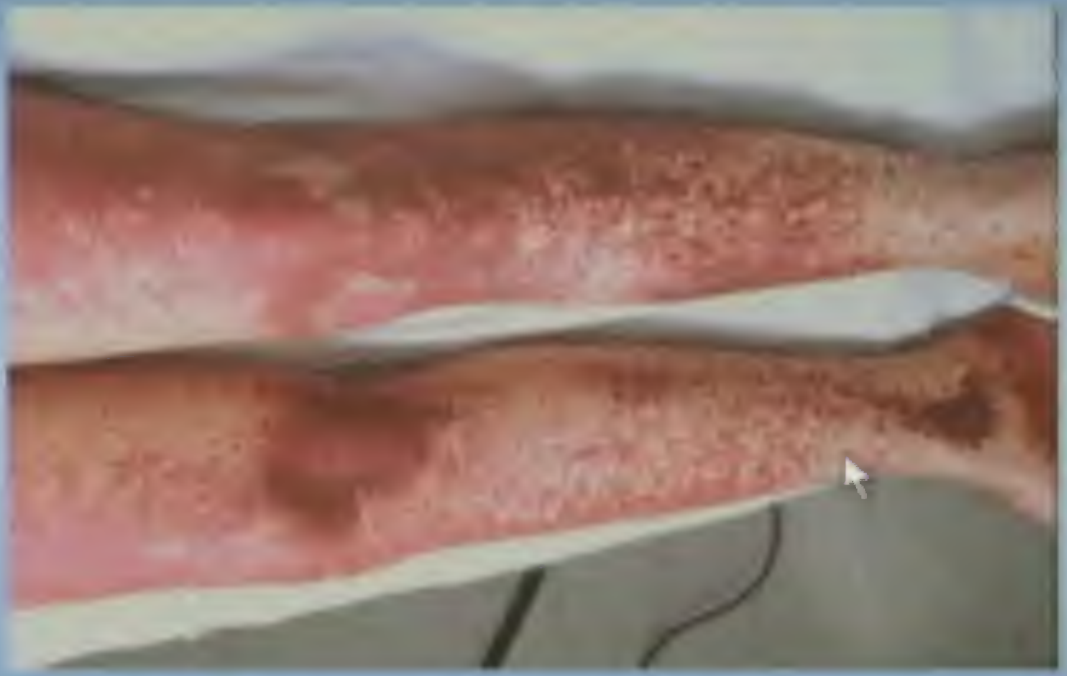
Renal Transplantation

- Average wait list is 2–4 years
- Post-transplantation graft rejection prevention
  1. Cyclosporine
  2. Tacrolimus
  3. Mycophenolate

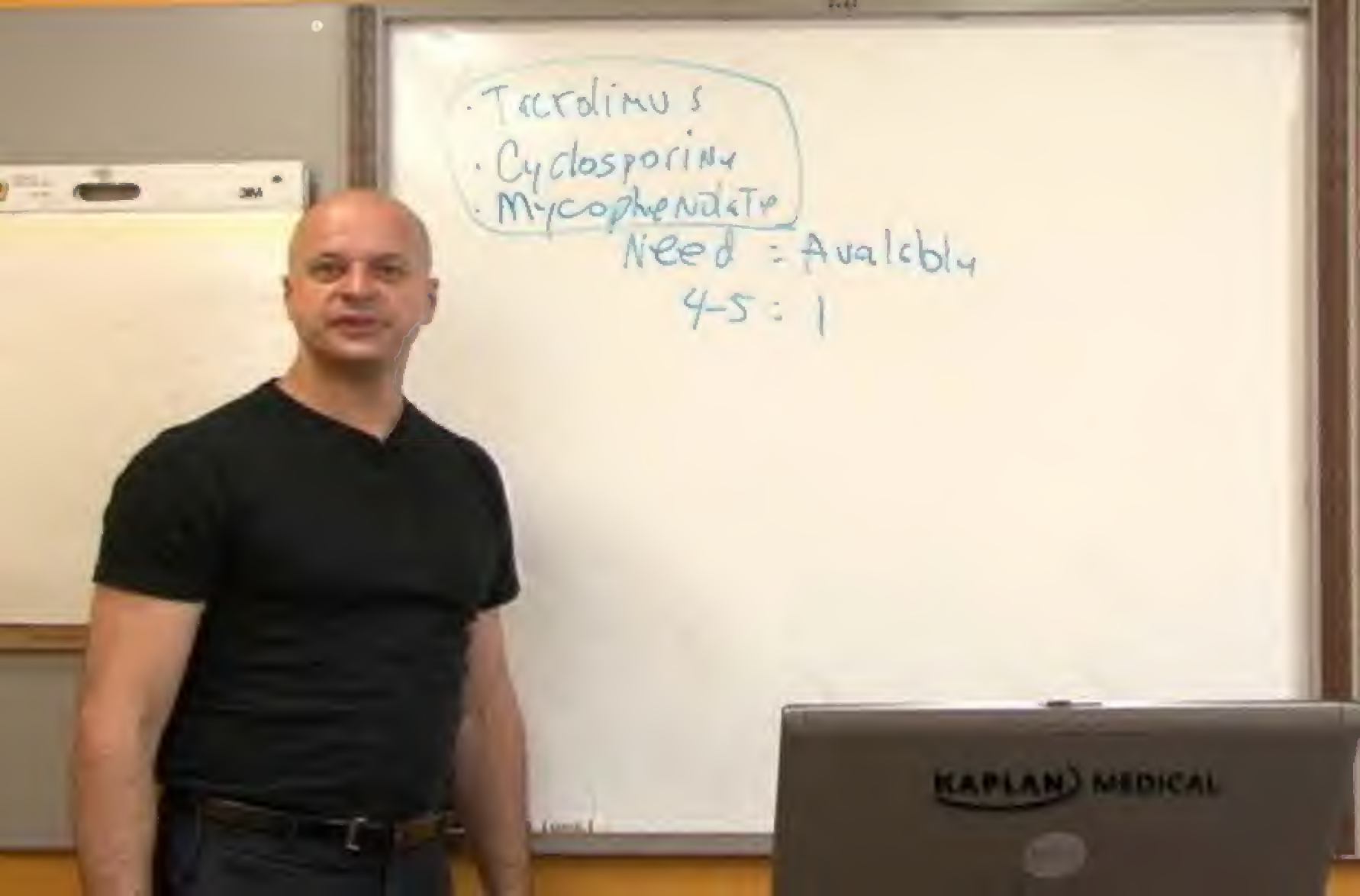
Graft vs. Host Disease



Severe Graft vs. Host Disease



Reproduced with permission from the European College for Hospital Teachers and Play Therapists by net, sponsored by the Program Minerva of the European Commission


· Tacrolimus
· Cyclosporine
· Mycophenolate
Need : Available
4-5 : 1
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Fluid and Electrolyte Disorders

Hyponatremia

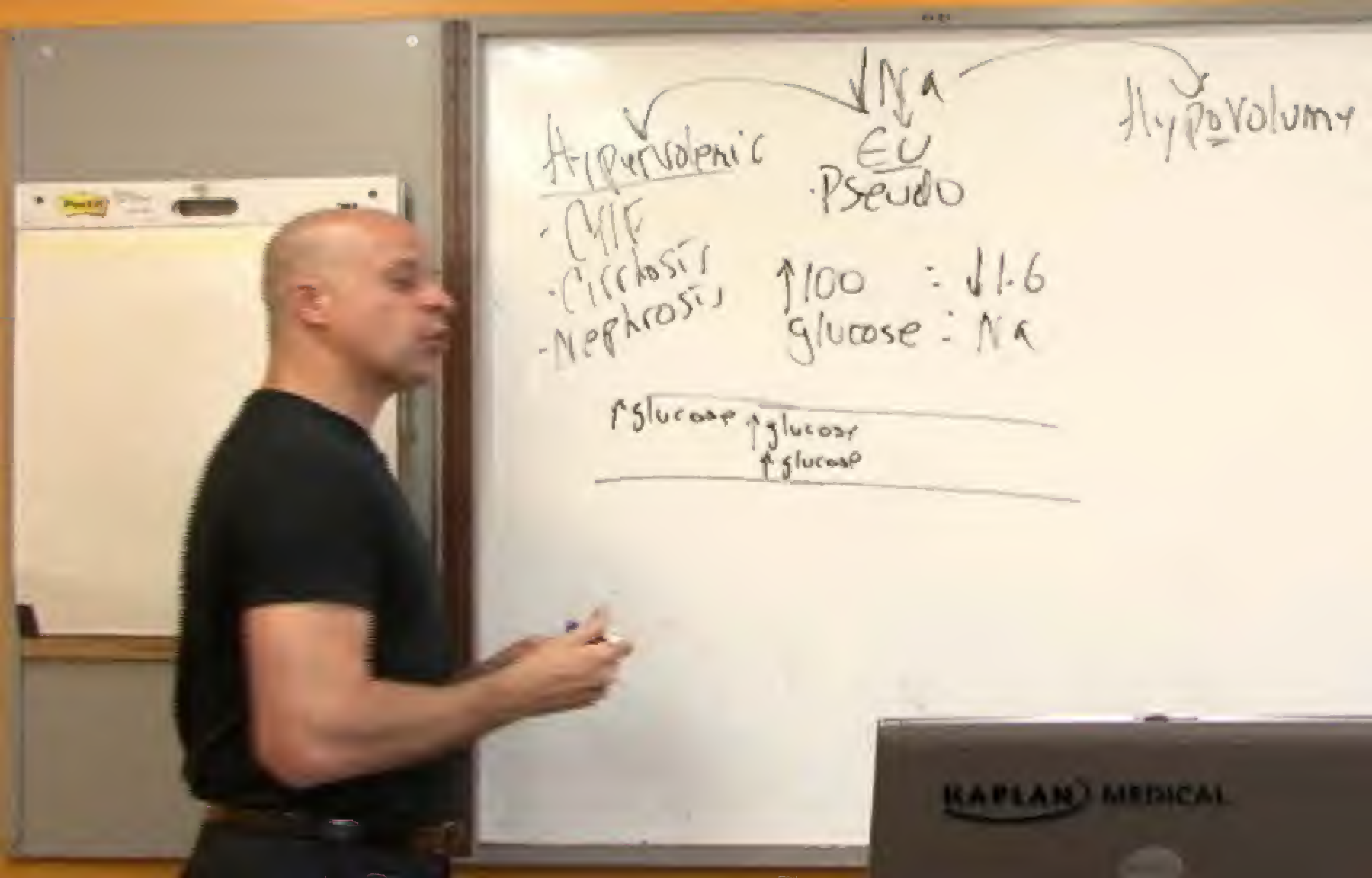
- Serum sodium <135 mEq/L
- Free water retention or urinary sodium loss
- Serum sodium largely determines serum osmolarity
  - Serum osmolarity = (2 x sodium) + BUN/2.8 + glucose/18
  - If serum glucose and BUN are normal, then serum osmolarity is 2 x sodium + 10

Hyponatremia

- Presentation
  1. Neurologic symptoms
- Treatment
  - Mild hyponatremia → fluid restriction
  - Moderate hyponatremia → 0.9% normal saline + loop diuretic
  - Severe hyponatremia → 3% hypertonic saline
- Complications of treatment
  - **Rapid correction of serum sodium → central pontine myelinolysis!!**

Hyponatremia— Specific Etiologies

- *Pseudohyponatremia*
  1. Total body sodium is **normal**
  2. Serum sodium is **artificially low**
  3. Treat the etiology:
     - Hyperglycemia ↓ serum sodium by 1.6 mEq/L per 100 mg/dL increase
     - Hyperlipidemia
- *Hypervolemia (↑ ECF)*


↓Na
Hypervolemic
- CHF
- Cirrhosis
- Nephrosis
Euvolemic
- Pseudo
↑100 : ↓1.6
Glucose : Na
↑glucose
↑glucose
↑glucose
Hypovolumy
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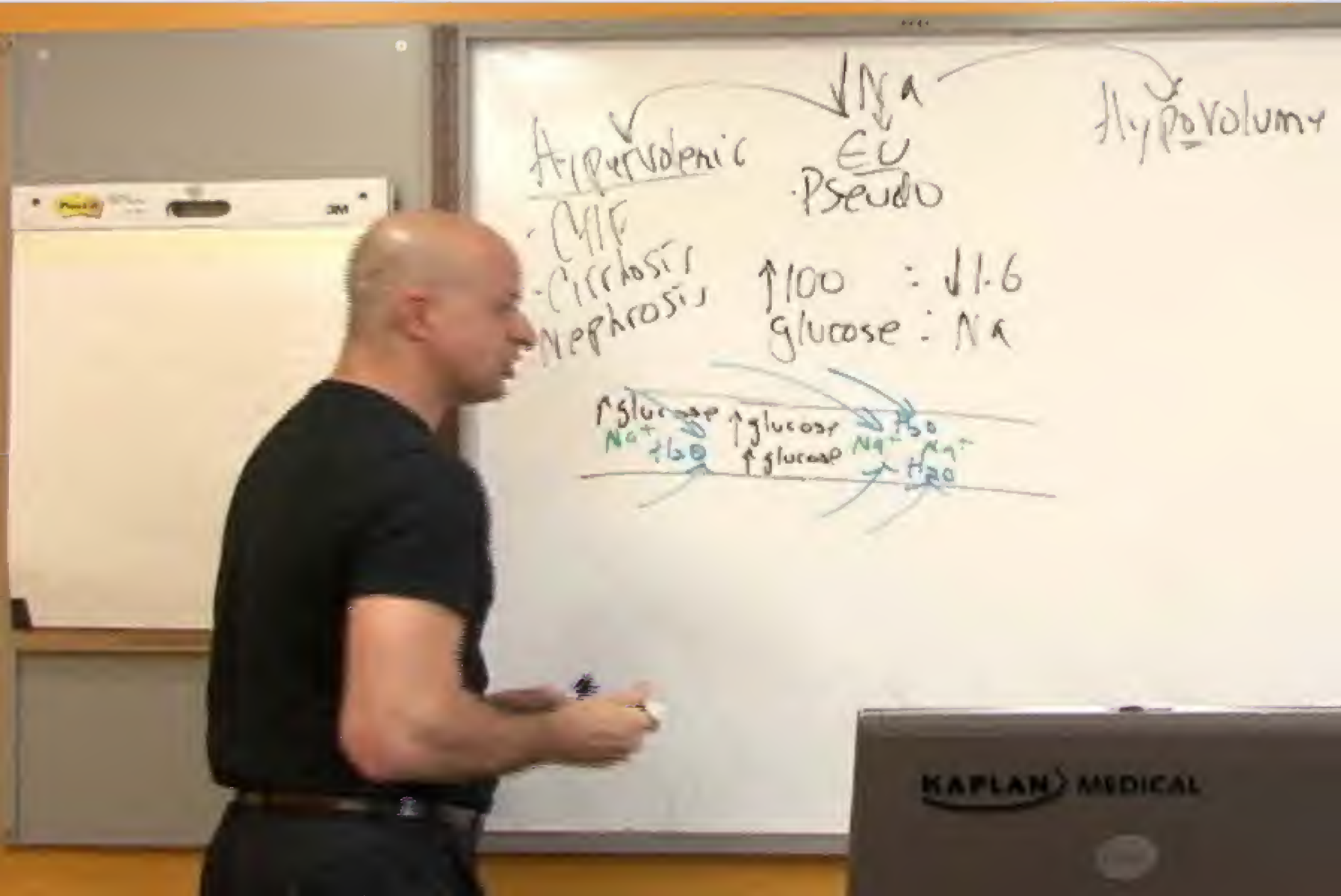
↓Na
Hypervolemic
- CHF
- Cirrhosis
Nephrosis
EU
Pseudo
↑100 : ↓1.6
glucose : Na
hypovolumy
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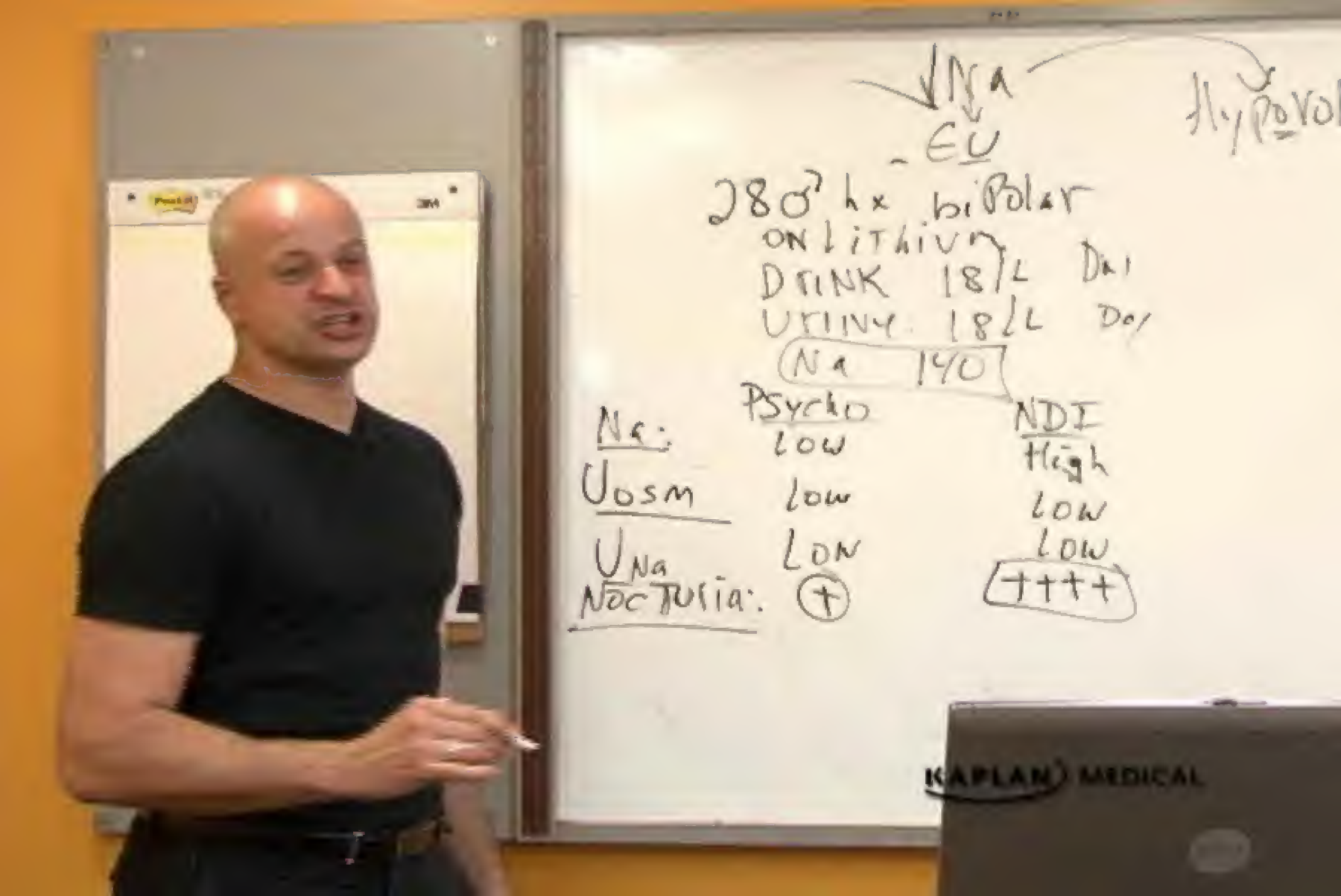
Hyponatremia— Specific Etiologies

- *Hypovolemia (↓ ECF)*

Urine Na <10	Urine Na >10
Dehydration	Diuretics
Vomiting	ACE inhibitors
Diarrhea	Renal salt wasting
Sweating	Addison disease
	Cerebral sodium wasting

Hyponatremia— Specific Etiologies

- *Euvolemia*
  1. Psychogenic polydipsia
  2. Hypothyroidism
  3. Diuretics
  4. ACE inhibitors
  5. Endurance exercise
  6. SIADH


↓Na
↓EU
Hypovol
80♂ hx bipolar
on Lithium
DRINK 18/L Dai
URINE 18/L Dai
Na 140
PSYCHO
NDI
Na: low High
Uosm low low
UNa low low
Nocturia: + ++++
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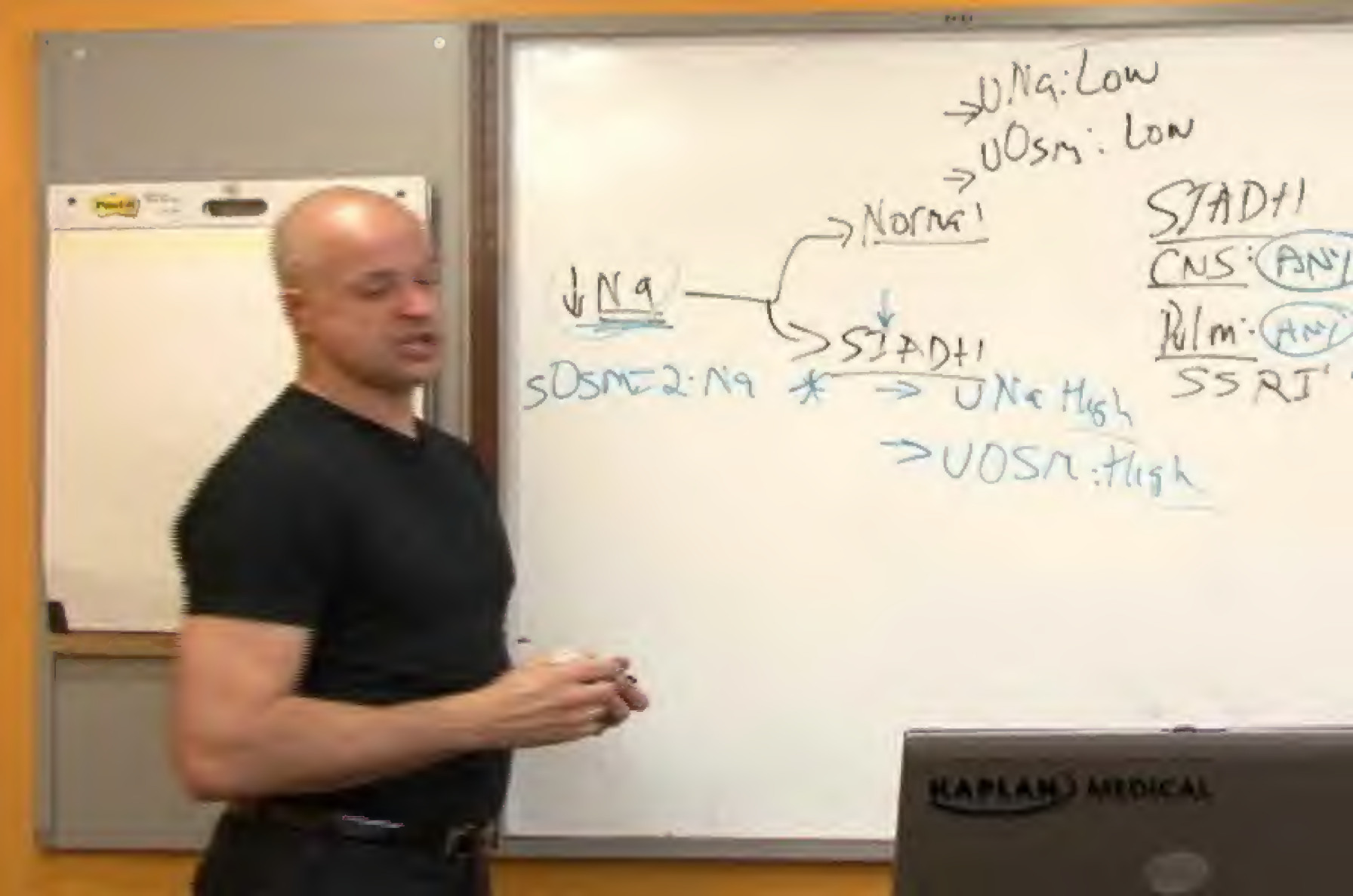
Hyponatremia— Specific Etiologies

- SIADH
  1. *Etiology, organic*: CNS disease, pulmonary disease, neoplastic disease
  2. *Etiology, inorganic*: SSRIs, TCAs, haloperidol, cyclophosphamide, vincristine, carbamazepine
  3. Diagnosis → Increased urine osmolarity and sodium (osmolarity of >100 is suggestive)
  4. Most accurate test: **elevated ADH**
  5. Treatment
     - Chronic SIADH: demeclocycline or lithium


↓Na
→Normal
→UNa: Low
→UOsm: Low
SIADH
CNS: ANS
Rx/m: ANS
SSRI
SIADH
sOsm = 2·Na
* → UNa High
→UOsm: High
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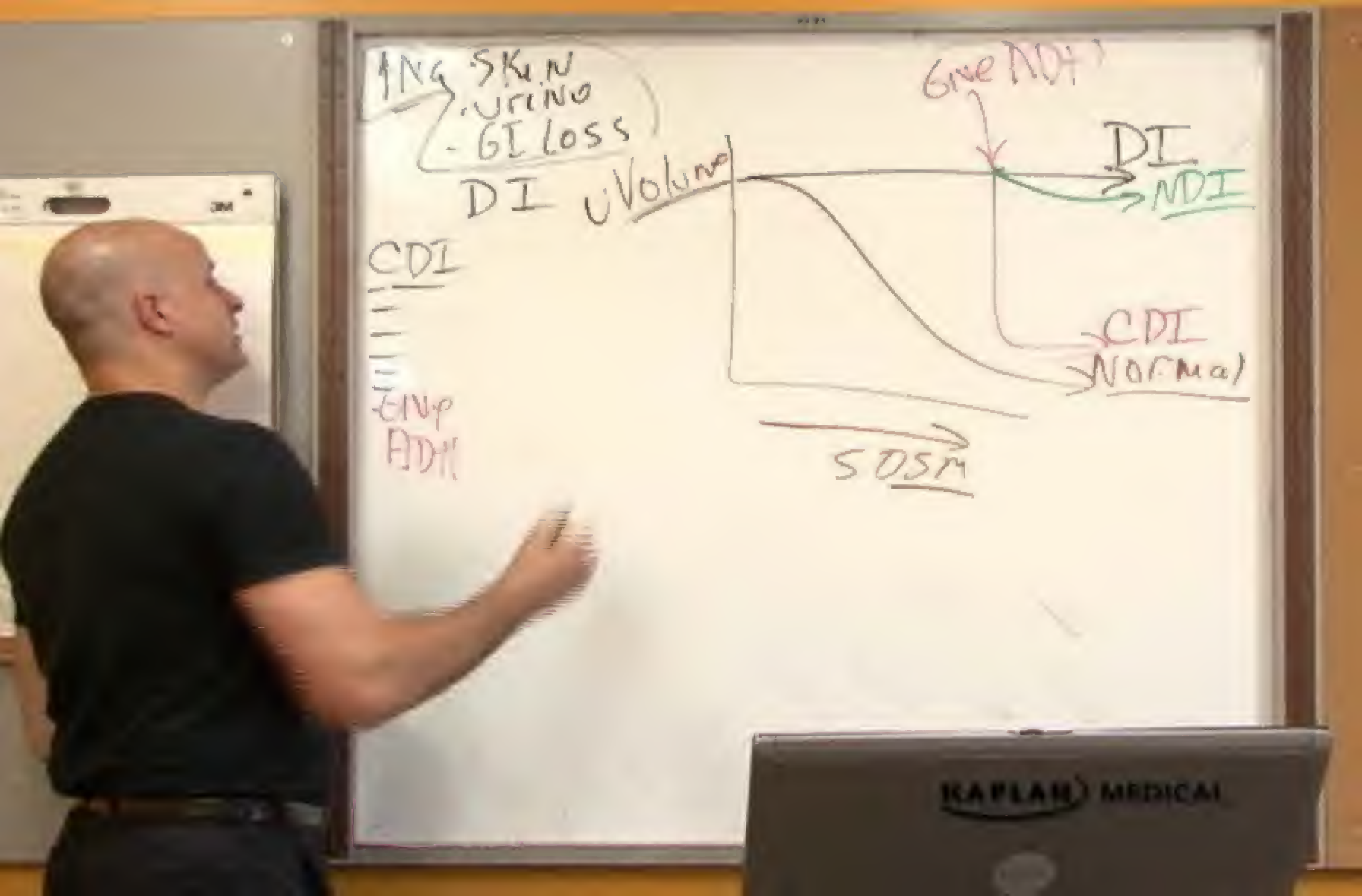
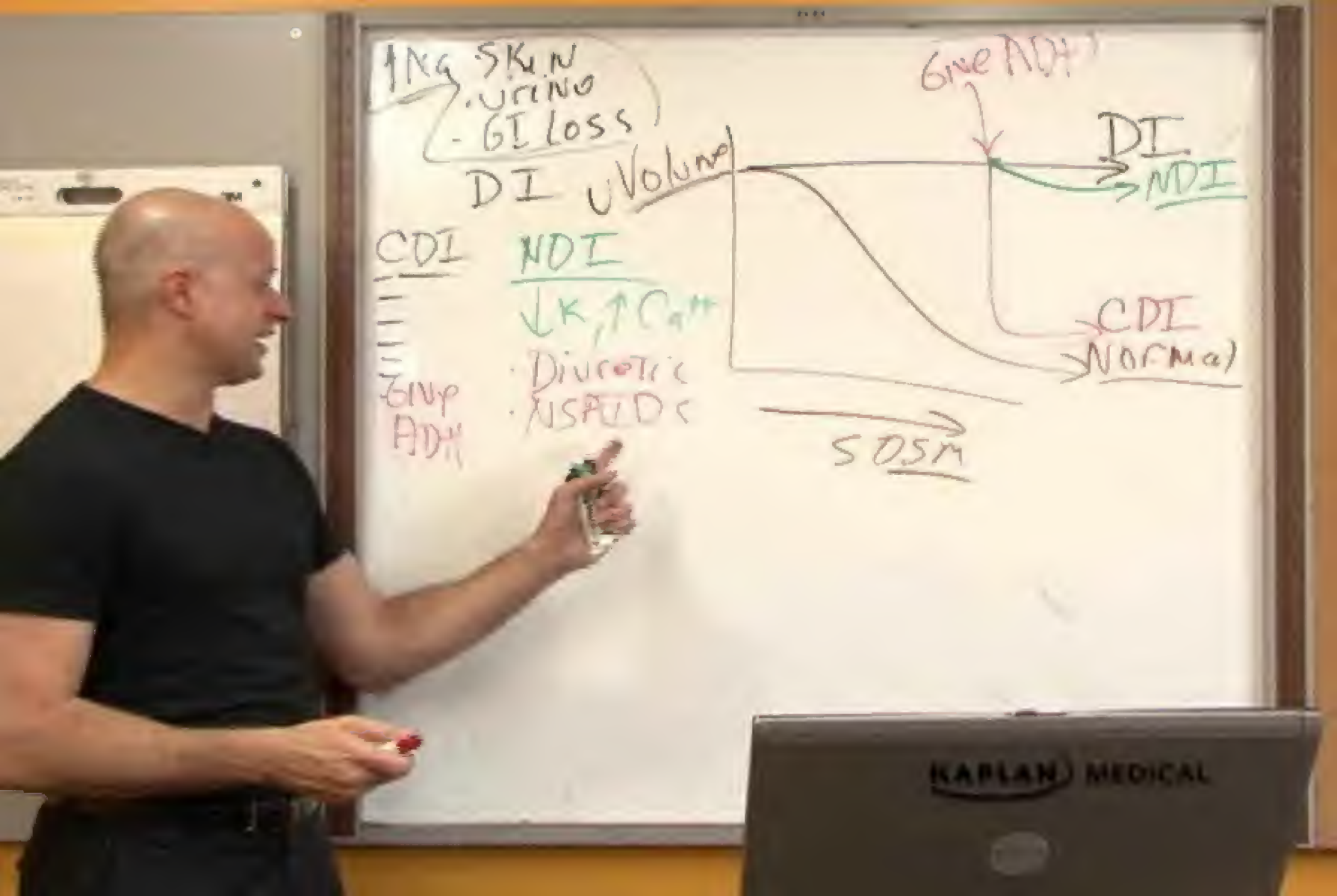
Hypernatremia— Etiology

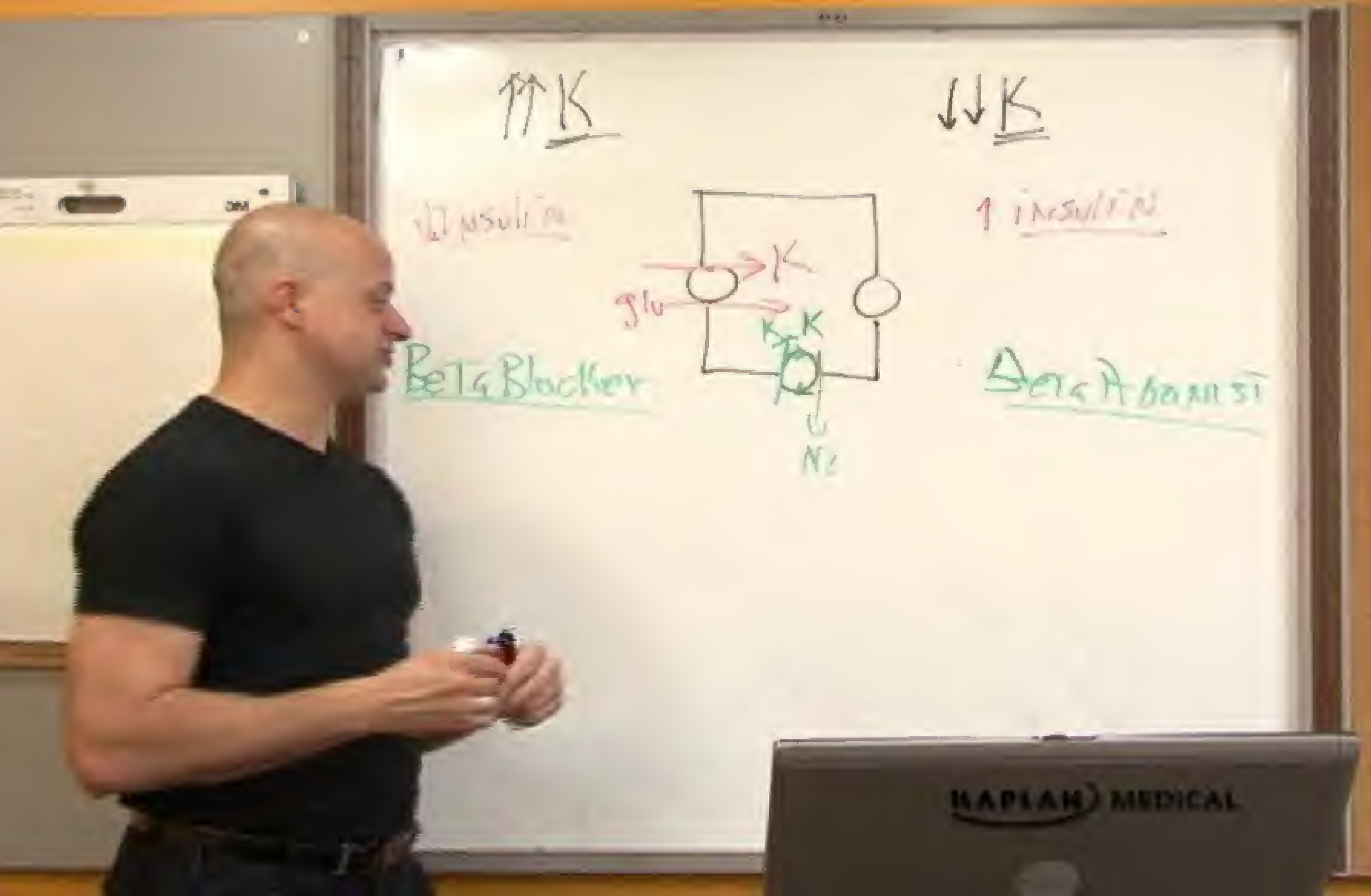
- Insensible losses
- GI loss
- Transcellular shift
- Renal
  1. Nephrogenic diabetes insipidus
  2. Central diabetes insipidus
  3. Idiopathic (most common), trauma, infections, tumors, granulomas, hypoxic brain damage
  4. Osmotic diuresis

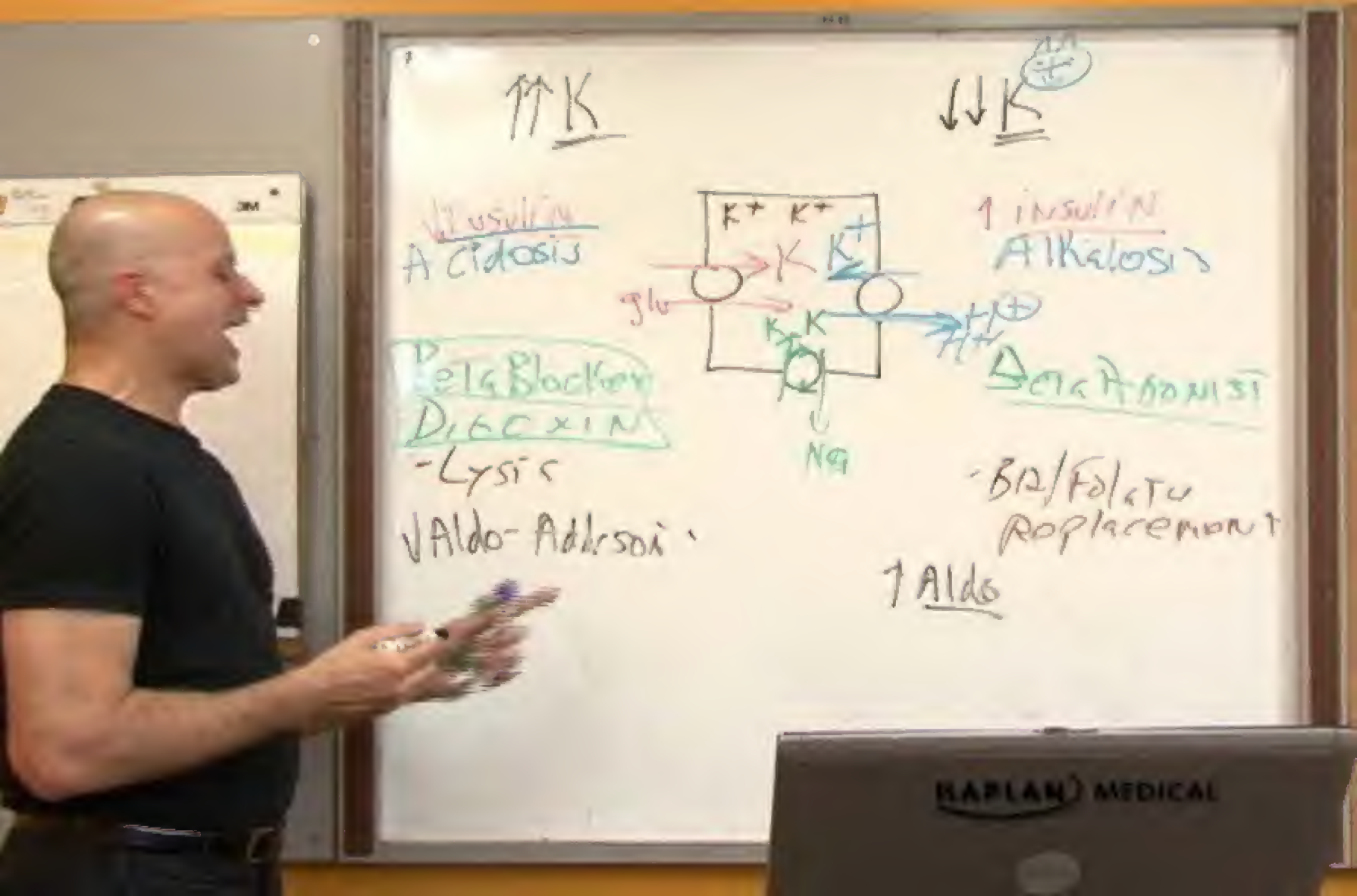
Hypernatremia— Etiology

- Presentation
  1. Primarily neurologic
- Diagnosis
  - Watching for a decrease in urine volume after administering ADH → central diabetes insipidus
- Treatment
  1. CDI → correct underlying cause, give vasopressin
  2. NDI → correct underlying cause, diuretic or NSAIDs


↑Na SKIN
↑URINE
- GI loss
DI uVolume
Give ADH
DI
NDI
CDI
CDI
Normal
↓Na
ADH
SOSM


INC SKIN
URINE
- GI loss
DI uVolume
Give ADH
DI
NDI
CDI
NDI
↓K, ↑Ca++
· Diuretic
· NSAIDs
Give ADH
CDI
Normal
SOSM
KAPLAN MEDICAL


↑↑K
↓↓K
insulin
↑ insulin
glu
K
Beta Blocker
KAPLAN MEDICAL


↑↑K
↓↓K
↓↓ insulin
Acidosis
K+ K+
K K+
Glu
K K
Na
↑ insulin
Alkalosis
Beta Blocker
Digoxin
-Lysis
↓Aldo- Addison
-B12/Folate
Replacement
↑Aldo
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Hypokalemia

- Etiology
  1. GI loss
  2. Increased aldosterone states: Conn syndrome, licorice, Bartter syndrome, or Cushing disease
  3. Low magnesium
- Presentation
  1. Muscle and heart: weakness, arrhythmias
  2. Nephrogenic DI
- Diagnosis
  - EKG: **T-wave flattening** and **U-wave**

Hypokalemia

- Treatment
  1. Correct underlying cause
  2. Repletion
     - IV maximum of 10–20 mEq/hr
     - Oral: 200–400 mg/point of K decrease
     - GI tract slows absorption, dextrose ↑ K entry, use ½ NS or NS
     - Potential complication of rapid correction is **fatal arrhythmia**
     - Total body requirement is 4-5 mEq/kg/point decrease in K
     - **Do not use IV dextrose!**

Hyperkalemia— Etiology

- Increased intake, usually with impaired excretion
- Cellular shift
  1. Pseudohyperkalemia
  2. Acidosis
  3. Insulin deficiency
  4. Tissue breakdown
  5. Periodic paralysis
- Decreased urinary excretion
  1. Renal failure
  2. Hypoaldosteronism
  3. Adrenal insufficiency or adrenalectomy
  4. Potassium-sparing diuretics
  5. NSAIDs

Hyperkalemia— Presentation and Diagnosis

- Presentation
  1. Muscle weakness with K > 6.5
  2. Abnormal cardiac conduction
- Diagnosis
  - EKG: peaked T-waves, wide QRS, short QT, or prolonged P-R

Hyperkalemia— Treatment

- Treatment
  1. Emergently (EKG changes): calcium chloride
  2. Sodium bicarbonate
  3. Glucose + insulin
  4. Diuretics, β-agonists
  5. Kayexalate ®
  6. Dialysis

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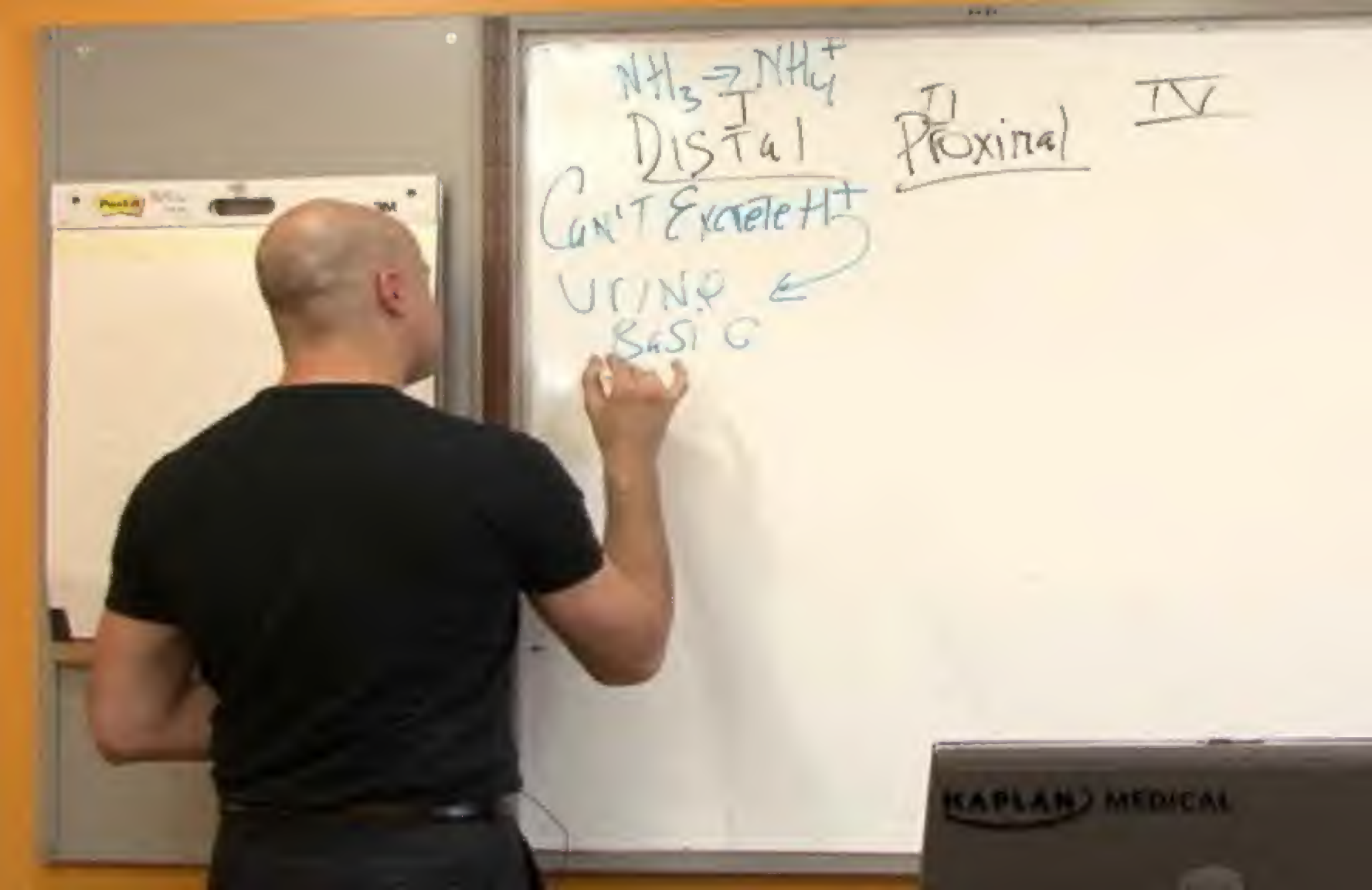
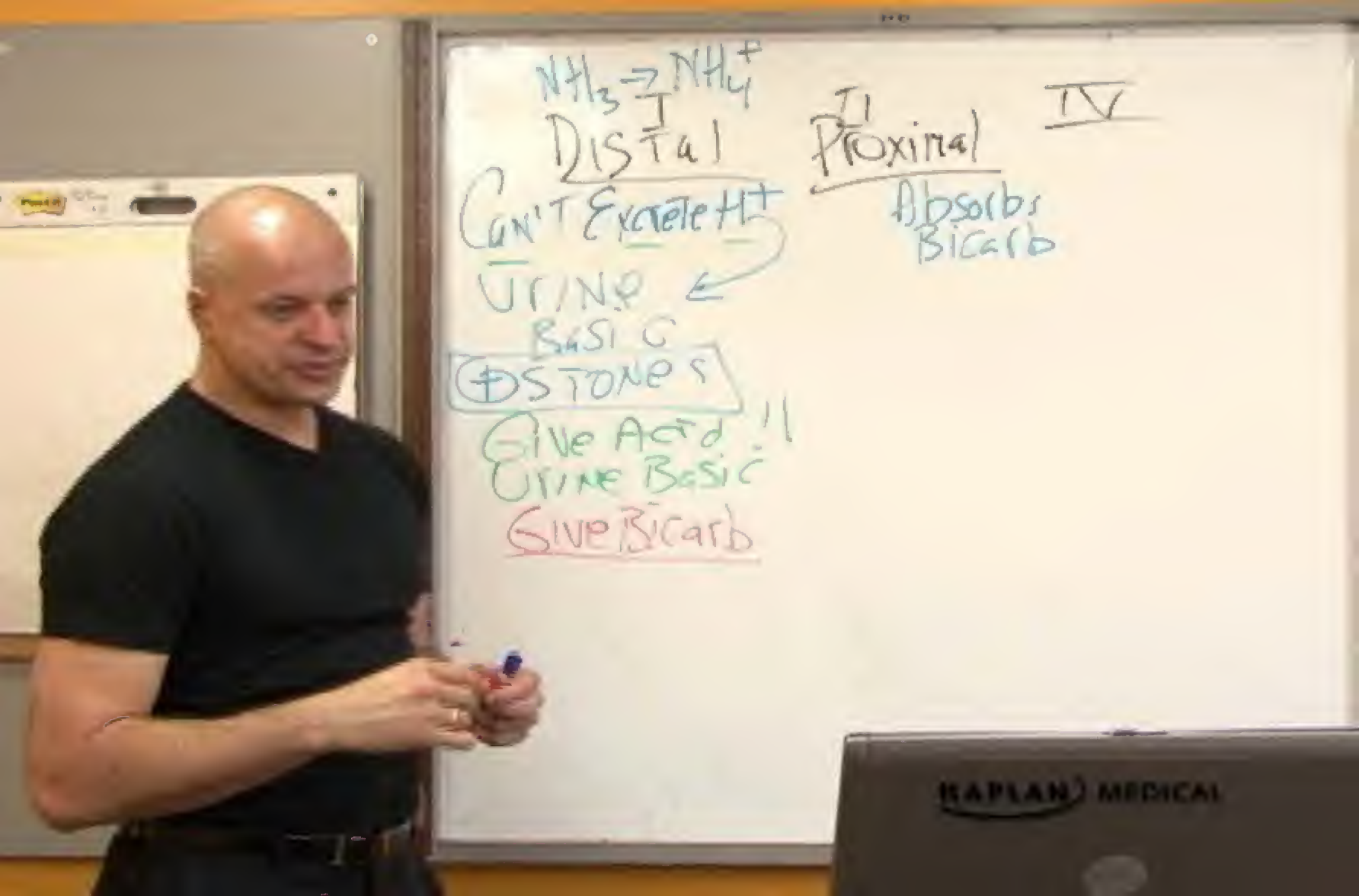
Renal Tubular Acidosis


$NH_3 \rightarrow NH_4^+$
Distal
Can't Excrete H^+
Urine
Basic
II
Proximal
IV
KAPLAN MEDICAL

Renal Tubular Acidosis Type I (Distal)

- Etiology
  1. Usually sporadic, secondary to autoimmune disease, drugs, nephrocalcinosis, sickle cell, chronic infection, familial, chronic hepatitis
- Presentation
  1. Urine pH >5.4
  2. Hyperaldosteronism and hypokalemia
  3. **Nephrocalcinosis and nephrolithiasis**


$NH_3 \rightarrow NH_4^+$
Distal
Can't Excrete H^+
Urine
Basic
(+) Stones
Give Acid !!
Urine Basic
Give Bicarb
II
Proximal
Absorbs
Bicarb
IV
KAPLAN MEDICAL

Renal Tubular Acidosis Type I (Distal)

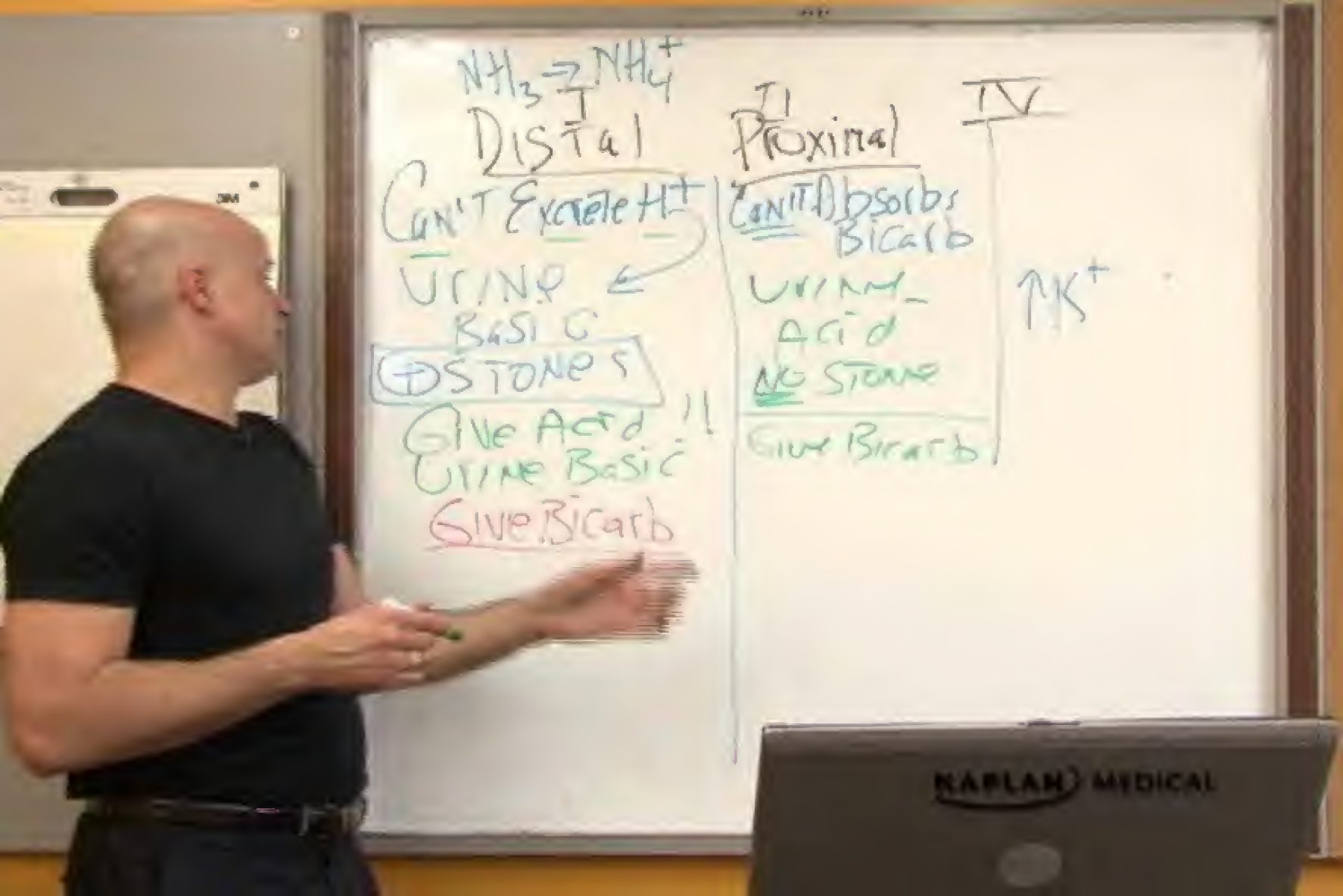
- Diagnosis
  1. Acid load test → urine pH remains elevated
  2. Hypokalemia
- Treatment
  1. Oral bicarbonate
  2. Potassium replacement

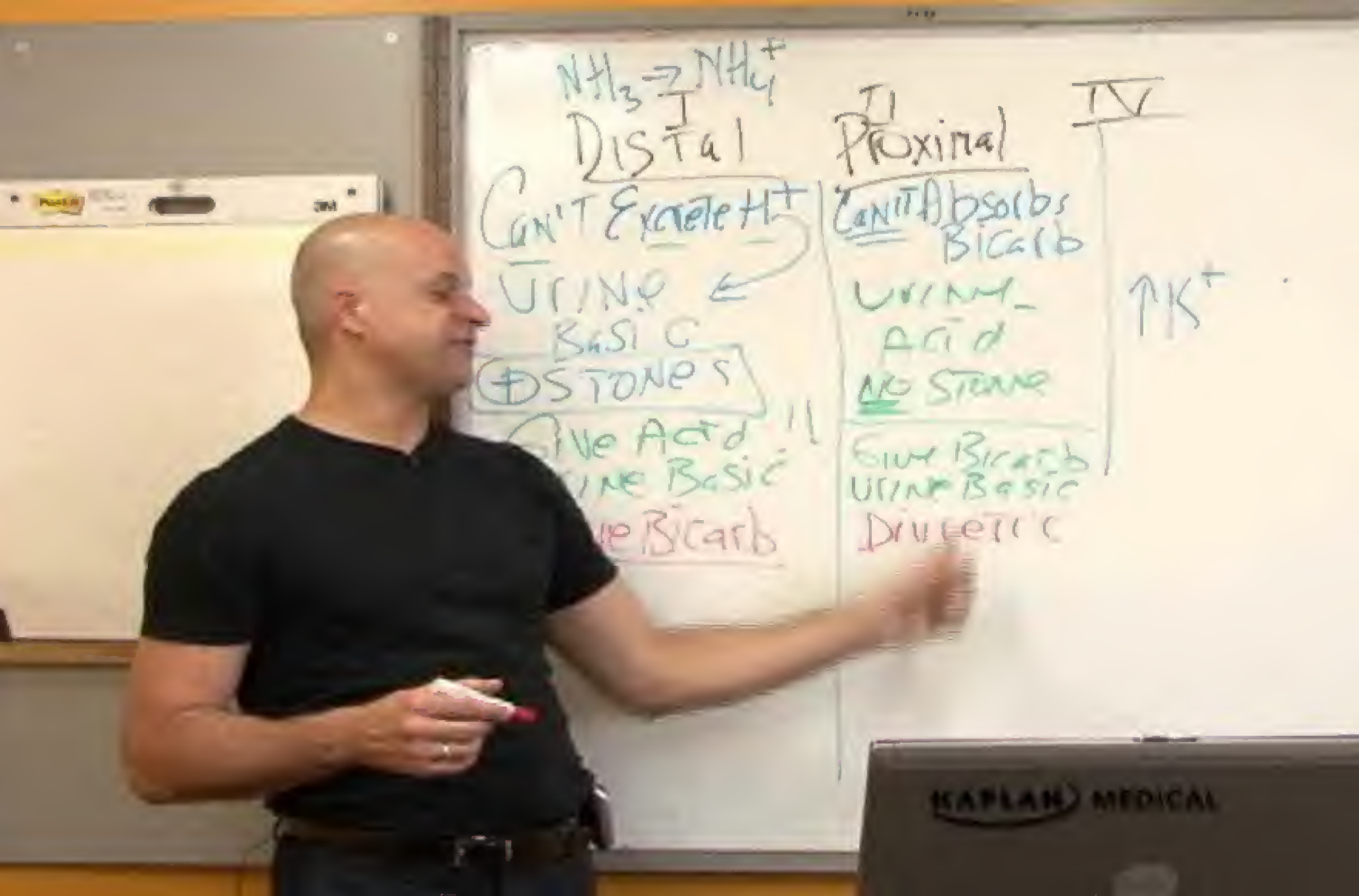
Renal Tubular Acidosis Type II (Proximal)

- Etiology
  1. Fanconi syndrome
  2. Wilson disease
  3. Amyloidosis
  4. Myeloma
  5. Acetazolamide
  6. Vitamin D deficiency, secondary hyperparathyroidism, chronic hypocalcemia
  7. Heavy metals
  8. Chronic hepatitis
  9. Autoimmune diseases

Renal Tubular Acidosis Type II (Proximal)

- Presentation
  1. Inability to absorb bicarbonate → urine pH <5.4
  2. Hypokalemia, serum bicarbonate 18–20
  3. Malabsorption of glucose, phosphate, urate and amino acids
  4. **Bone lesions (osteomalacia and rickets)**


$NH_3 \Rightarrow NH_4^+$
I
Distal
Can't Excrete H^+
Urine Basic
+ Stones
Give Acid !!
Urine Basic
Give Bicarb
II
Proximal
Can't Absorb Bicarb
Urine Acid
No Stone
Give Bicarb
IV
$\uparrow K^+$
KAPLAN MEDICAL

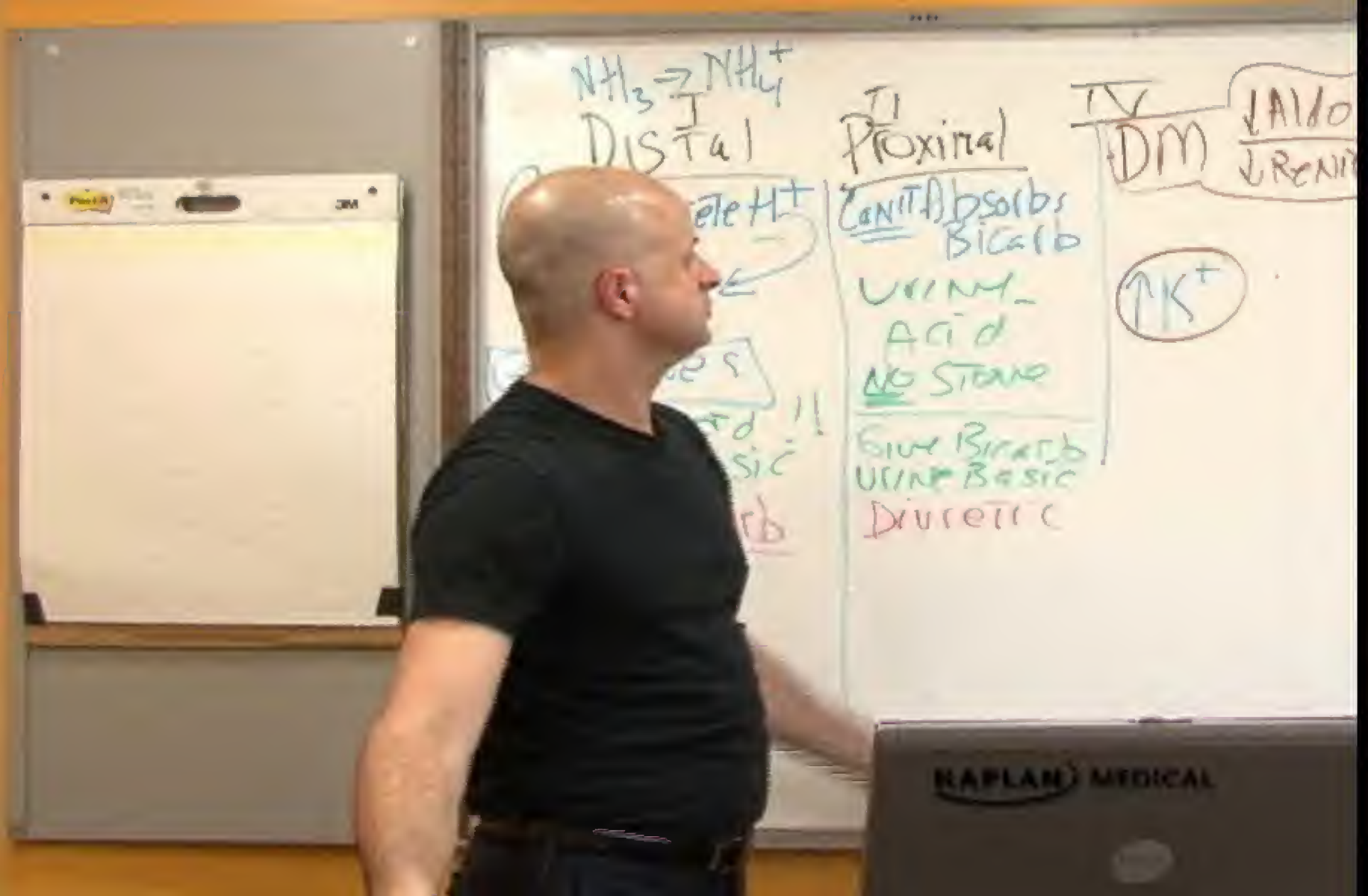

$NH_3 \rightarrow NH_4^+$
I
Distal
II
Proximal
IV
Can't Excrete H^+
Urine Basic
(+) Stones
Give Acid
Urine Basic
Give Bicarb
Can't Absorb Bicarb
Urine Acid
No Stone
Give Bicarb
Urine Basic
Diuretic
$\uparrow K^+$
KAPLAN MEDICAL

Renal Tubular Acidosis Type II (Proximal)

- Diagnosis
  - Unable to absorb IV bicarbonate → acidemia and basic urine
- Treatment
  - Potassium replacement
  - Large amounts of bicarbonates + thiazide diuretic

Hyporeninemic/ Hypoaldosteronism (Type IV)

- Etiology
  1. Aldosterone deficiency or adrenal insensitivity to angiotensin II
  2. Diabetes
  3. Addison disease
  4. Sickle cell disease
  5. Renal insufficiency
- Presentation
  1. Usually asymptomatic hyperkalemia
  2. Mild to moderate renal insufficiency
  3. Hyperchloremic metabolic acidosis (non-anion gap)


$NH_3 \rightarrow NH_4^+$
Distal
Proximal
IV
DM
↓ANG
↓RENIN
↑K^+
Urine Acid
NO STRAW
Urine Basic
Diuretic
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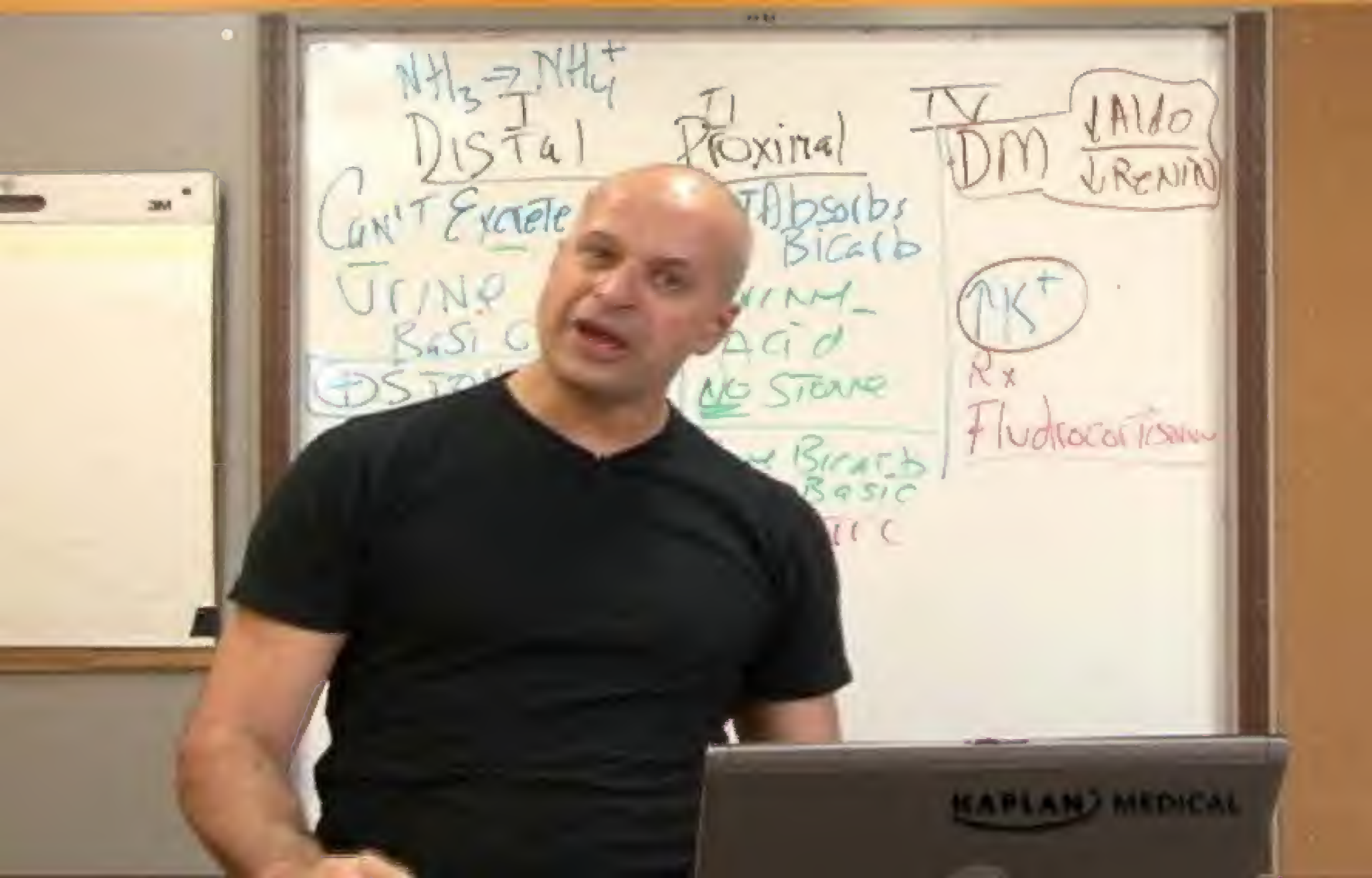
$NH_3 \rightleftharpoons NH_4^+$
Distal
Can't Excrete
Urine
Basic
Proximal
Reabsorbs
Bicarb
Acid
No Stone
Basic
DM
↓Aldo
↓Renin
↑K+
Rx
Fludrocortisone
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Renal Tubular Acidosis

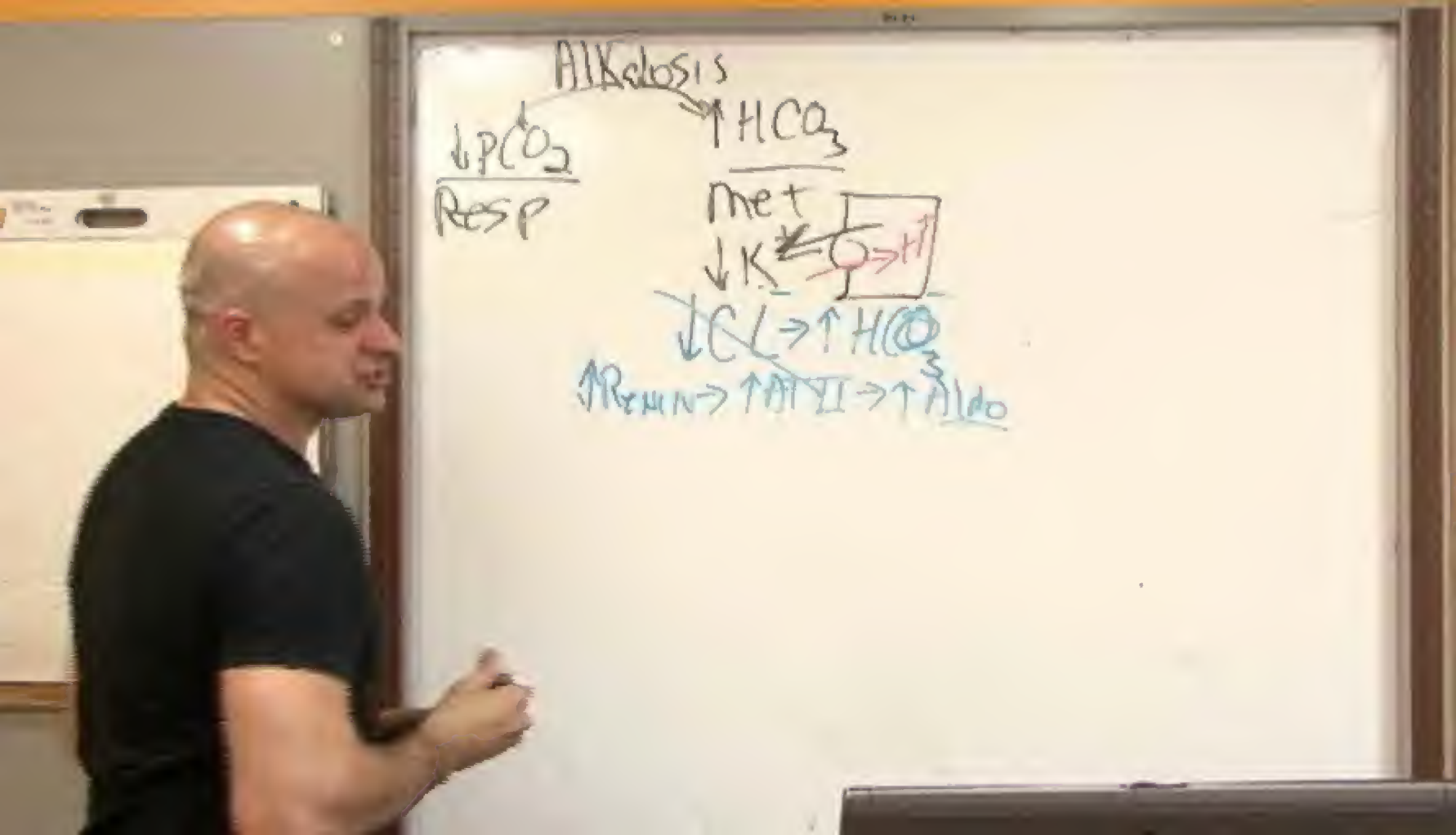
END

Metabolic Alkalosis

- H^+ Ion loss
  1. Exogenous steroids
  2. GI loss
  3. Renal loss
  4. Decreased chloride intake
  5. Diuretics
- HCO_3 + retention
  1. Bicarbonate administration
  2. Contraction alkalosis
  3. Milk-alkali syndrome
- H^+ movement into cells
  - Hypokalemia

Respiratory Alkalosis

- Hyperventilation of any cause
  1. Anemia
  2. Pulmonary embolus
  3. Sarcoidosis
  4. Anxiety and pain
  5. Progesterone, catecholamines
  6. Salicylates
  7. Hypoxia
  8. Cirrhosis


Alkalosis
↑HCO3
↓pCO2
Resp
met
↓K
O->H
↓Cl->↑HCO3
↑Renin->↑AT II->↑Aldo

Acidosis

Anion Gap =

$(Na+ + K+) - (HCO3^- + Cl^-)$

Normal: 8–14

Metabolic Acidosis

- Low anion gap
  1. Myeloma
  2. Low albumin
  3. Lithium
- Normal anion gap
  1. Diarrhea
  2. Renal tubular acidosis
  3. Ureterosigmoidoscopy

Metabolic Acidosis *(Cont'd)*

- Increased anion gap (LA MUD PIE)
  - **L**actate
  - **A**spirin
  - **M**ethanol
  - **U**remia
  - **D**iabetic ketoacidosis
  - **P**araldehyde, **P**ropylene glycol
  - **I**sopropyl alcohol, **I**NH
  - **E**thylene glycol


Alkalosis
↓PCO2
Resp
↑HCO3
Met
↓K
↓CL→↑HCO3
→↑ATII→↑Aldo
Acidosis
Na - (CL and Bicarb)
↑AG
Lactate
↓BP
Na+ (↓CL
↓↓HCO3
↑ lactate
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Alkalosis
↑HCO3
↓PCO2
Acidosis
↑AG
Lactate
↓BP
KAPLAN MEDICAL

Respiratory Acidosis

- Hypoventilation of any cause
  1. COPD
  2. Pickwickian syndrome
  3. Obesity
  4. Suffocations
  5. Opiates
  6. Sleep apnea
  7. Kyphoscoliosis
  8. Myopathies
  9. Neuropathy
  10. Effusion

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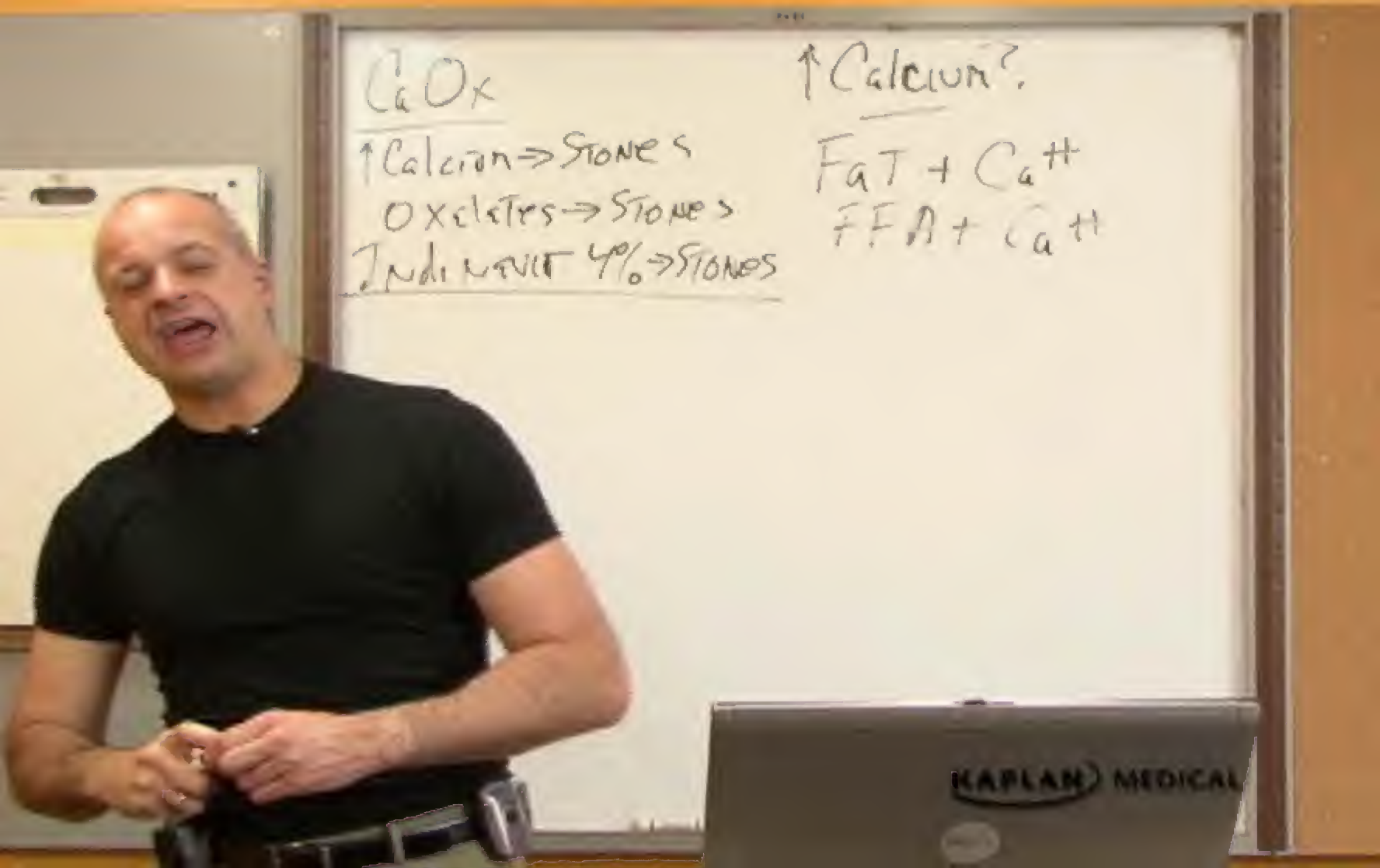
Nephrolithiasis

Nephrolithiasis— Etiology

- Incidence: 1-5% of the population
  - Composition of stones includes
    - Calcium oxalate → 70%
    - Calcium phosphate → 10%
    - Mg/aluminum/phosphate (struvite) → 5-10%
    - Uric acid → 5%
    - Cysteine → 1%
    - Indinavir


CaOx
↑Calcium⇒Stones
Oxalates⇒Stones
Indinavir 4%⇒Stones
↑Calcium?
FaT + Ca++
FFA + Ca++
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Hypercalciuria— Etiology

- *Increased absorption*
  1. Vitamin D intoxication
  2. ↑ Vitamin D with sarcoidosis and other granulomatous disease
  3. Familial
- *Idiopathic renal hypercalciuria*
- *Resorptive*
  1. Hyperparathyroidism (10-30% will present with stones)
  2. Multiple myeloma, metastasis, hypercalcemia of malignancy

Hyperoxaluria— Etiology

- Primarily familial
- Enteric

Fat malabsorption

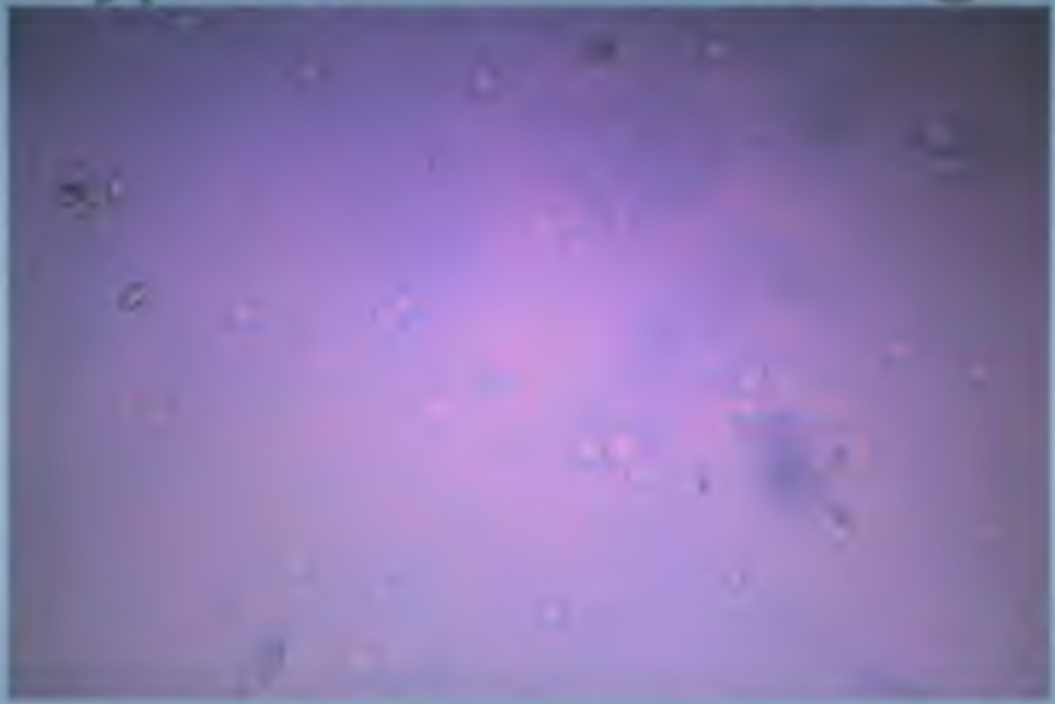
↓

Fat binds calcium

↓

Increased oxalate resorption

Hyperoxaluria— Findings



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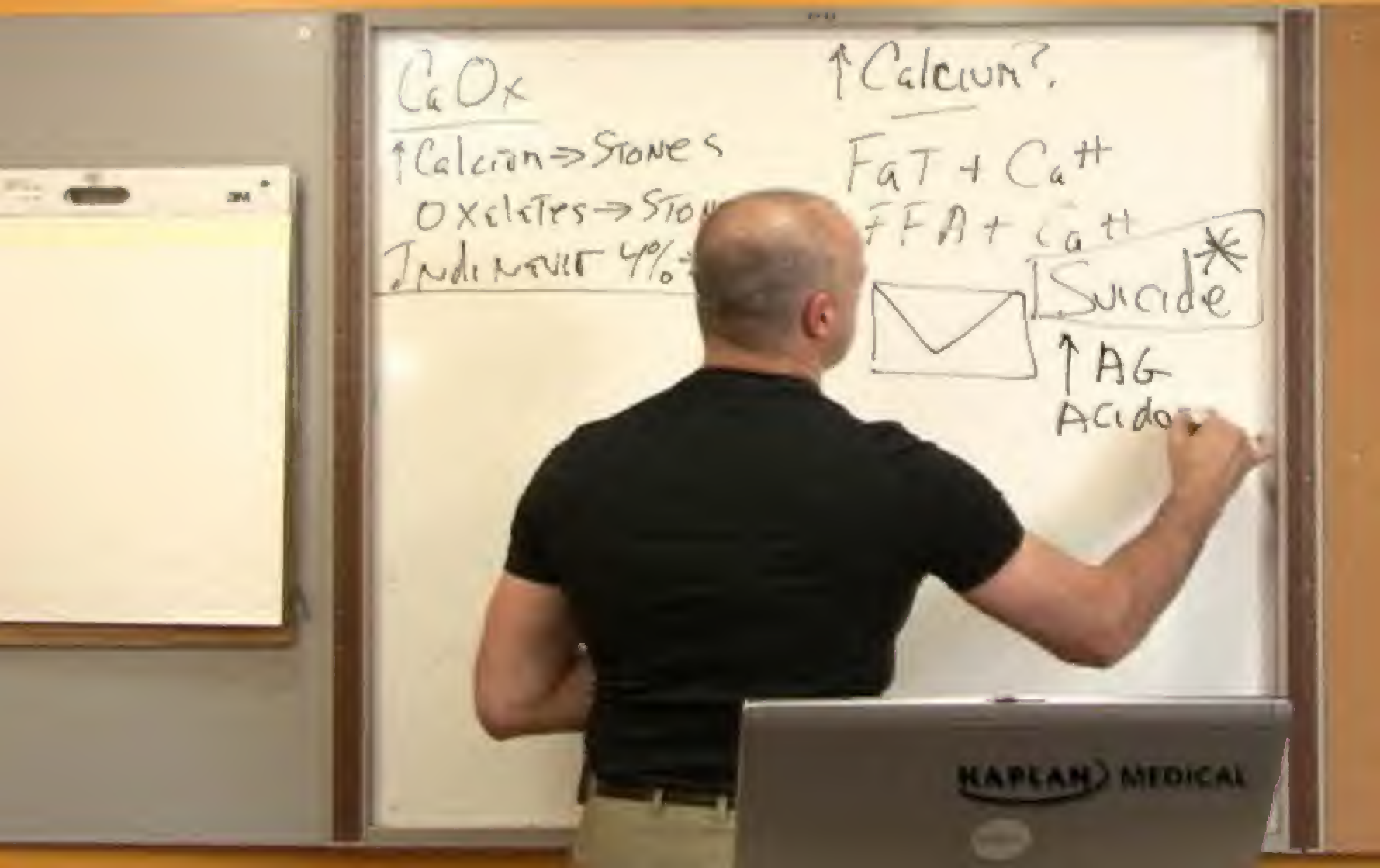

CaOx
↑Calcium⇒Stones
Oxalates⇒Sto
Indinavir 4%
↑Calcium?
FaT + Ca++
FFA + Ca++
Suicide
↑AG
Acido
KAPLAN MEDICAL

Other Stones to be Considered

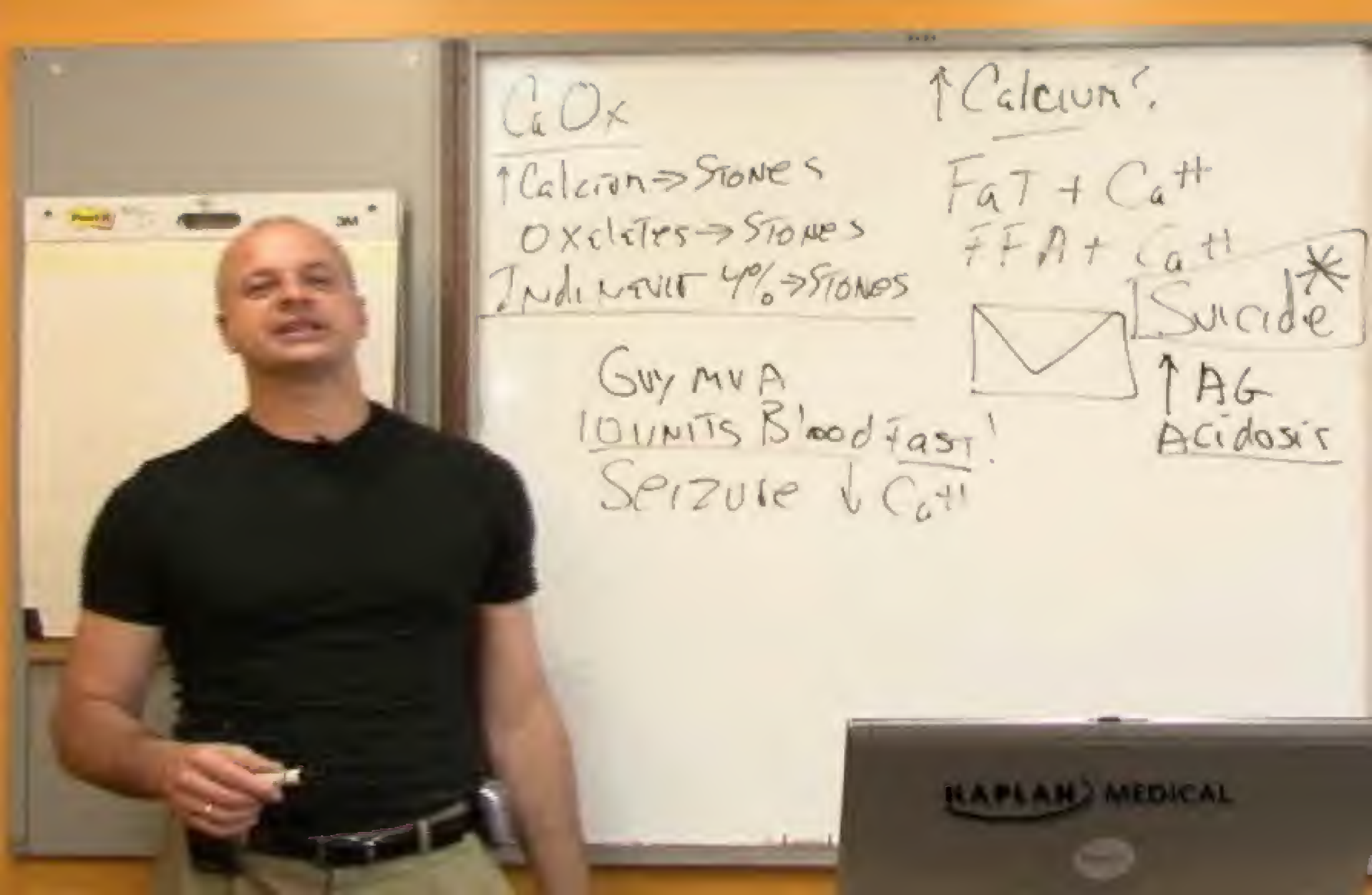
- Hypocitrauria
  - ↓ citrate leads to ↑ calcium absorption
  - Induced by acidosis
- Uric acid stones
  - Form in acidic urine
  - Causes include gout, leukemia, and Chron disease
  - **Radiolucent**

Other Stones to be Considered

- Cystinuria
  1. Genetic only
- Infection
  - Urease producing organisms → alkaline urine → struvite stones
  - *Proteus*, *Staphylococcus*, *Pseudomonas*, and *Klebsiella*

Stones— Clinical Findings

- Presentation
  1. **Constant, flank pain radiating to the groin**
  2. **Hematuria**
- Diagnosis
  1. Plain x-ray
  2. Ultrasound
  3. Strain the urine
  4. Serum and urine calcium
  5. IV pyelogram
  6. Helical CT without contrast


Ca Ox
↑Calcium⇒Stones
Oxalates⇒Stones
Indinavir ⇒Stones
↑Calcium?
FaT + Ca++
FFA + Ca++
Suicide
Guy MVA
10 units Blood fast!
Seizure ↓ Ca++
↑AG
Acidosis
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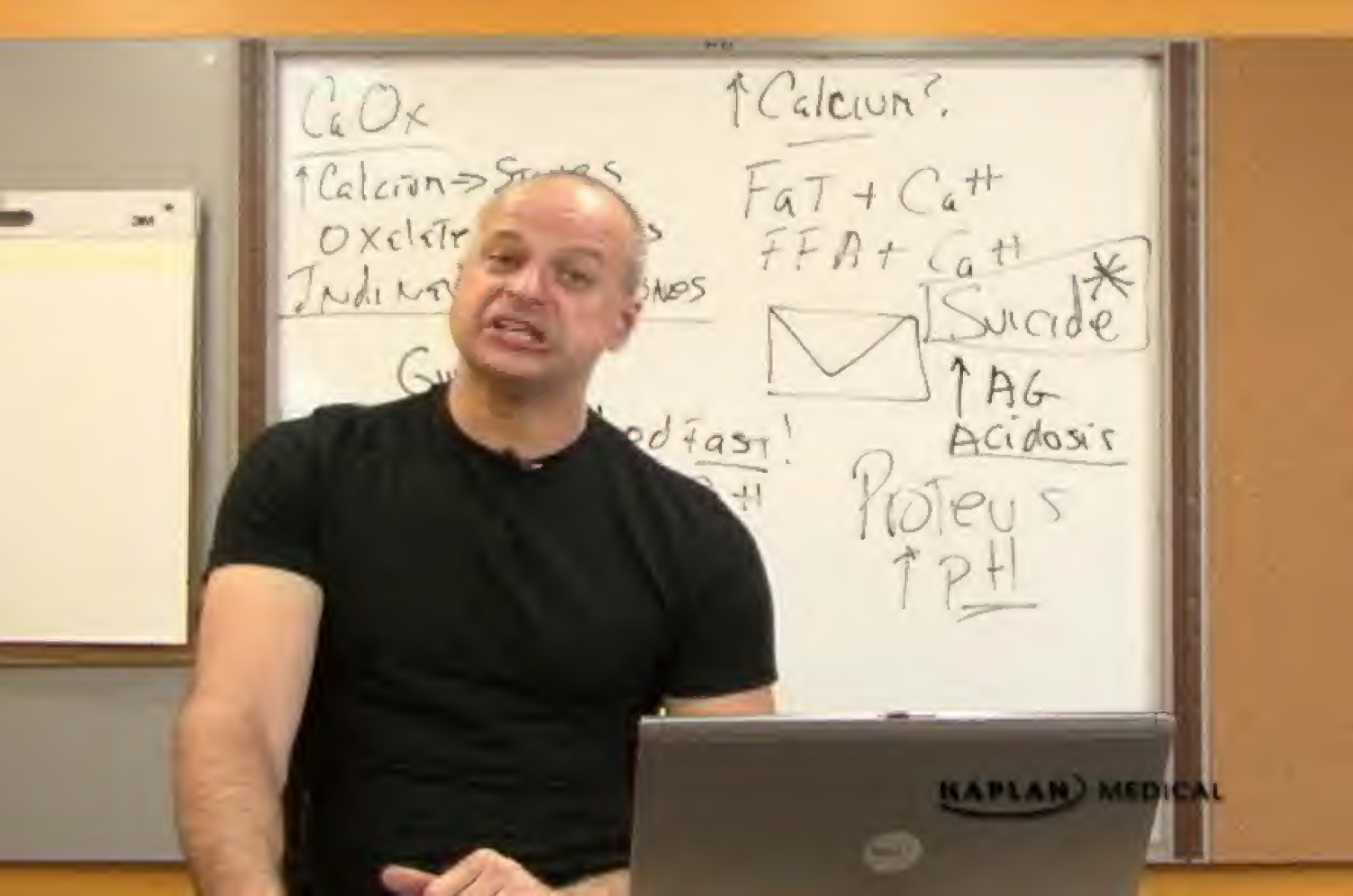
Ca Ox
↑Calcium?
↑Calcium=>
Oxalate
FaT + Ca++
FFA + Ca++
Suicide
↑AG
Acidosis
Proteus
↑PTH
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420 ED
Pain → Brain
headache
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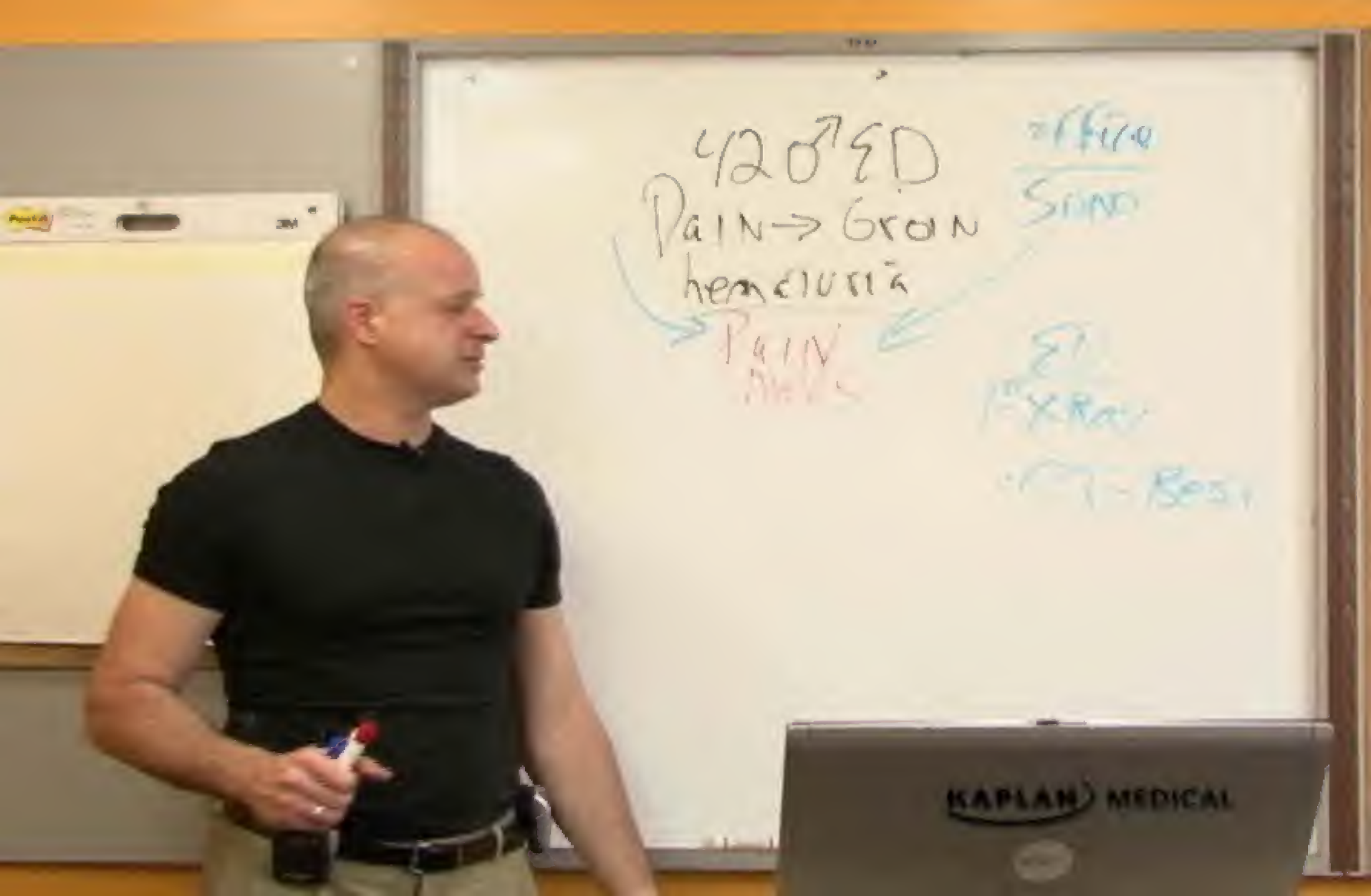
42 ♂ ED
Pain → Groin
hematuria
Pain
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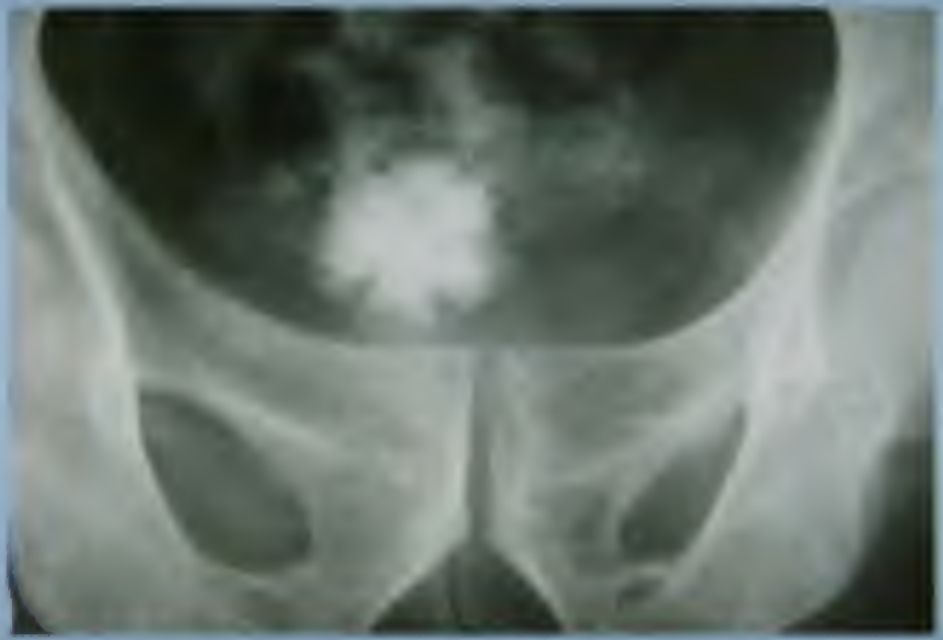
Large Kidney Stone on Abdominal X-ray



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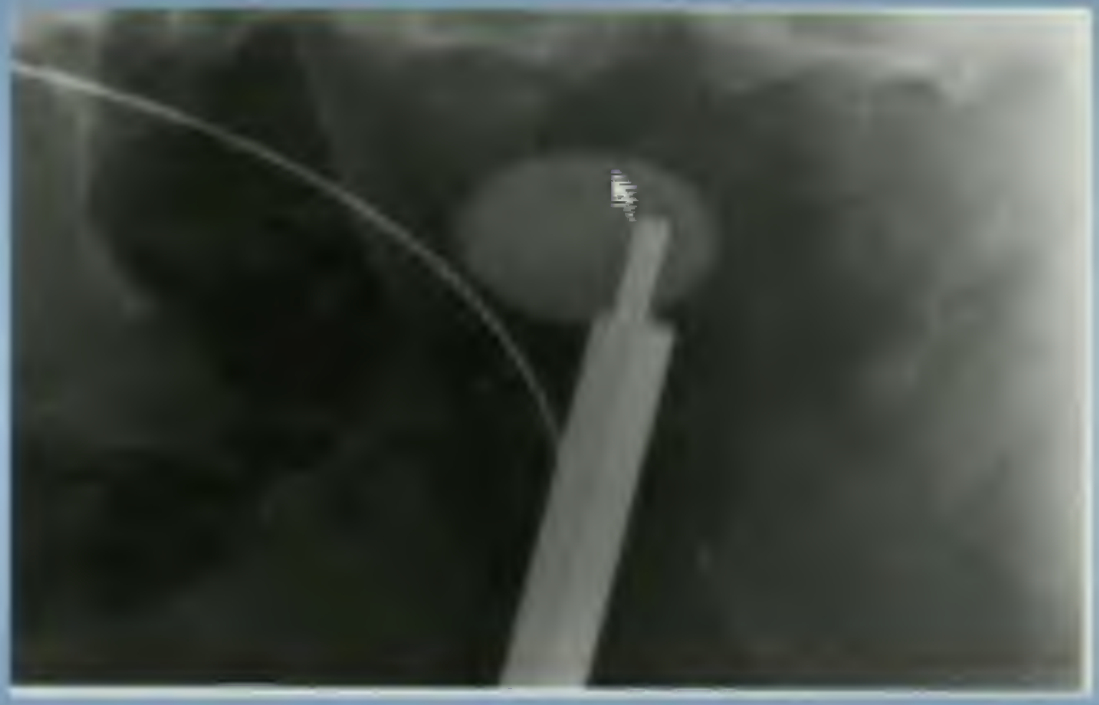
Stones— Management

- < 5 mm → pass spontaneously
- < 2 cm → shockwave lithotripsy
- Uretoscopy
- Percutaneous removal results in longer hospital stay
- **Analgesia, hydration** and **bed rest** are mainstays regardless of size

Shockwave Lithotripsy



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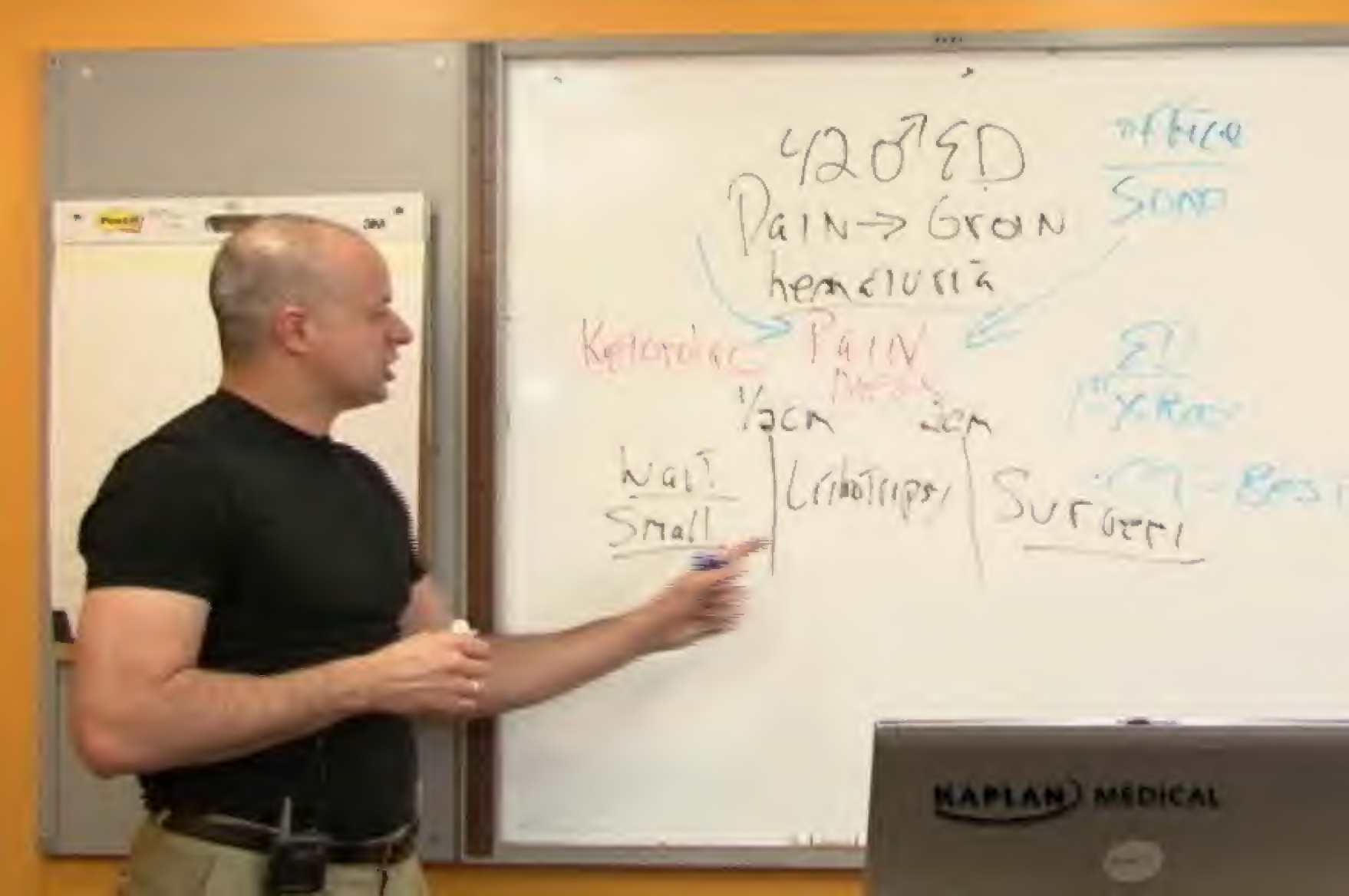
42♂ED
Pain → Gron
hematuria
Pain
½cm
2cm
Small
Lithotripsy
Surgery
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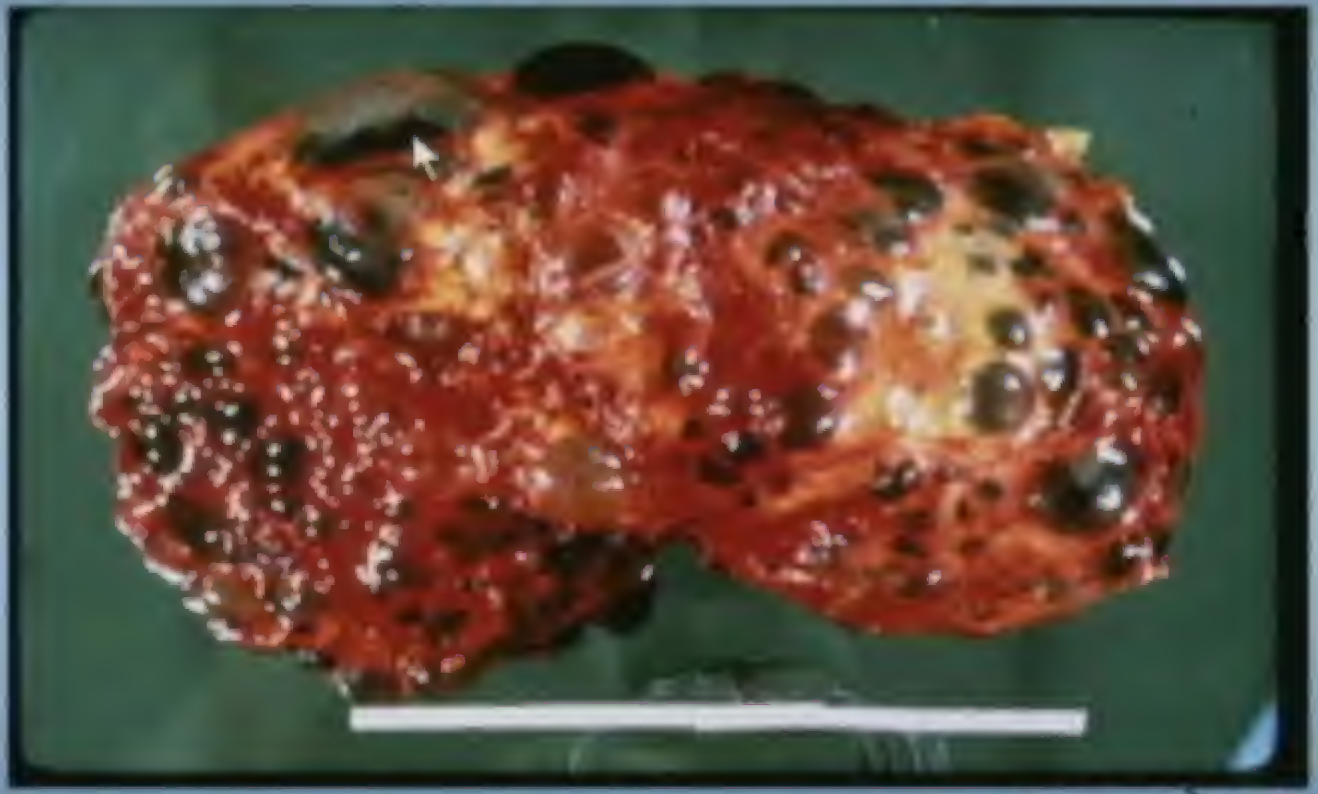
Hereditary Cystic Disease

Adult Polycystic Kidney Disease



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Adult Polycystic Kidney Disease

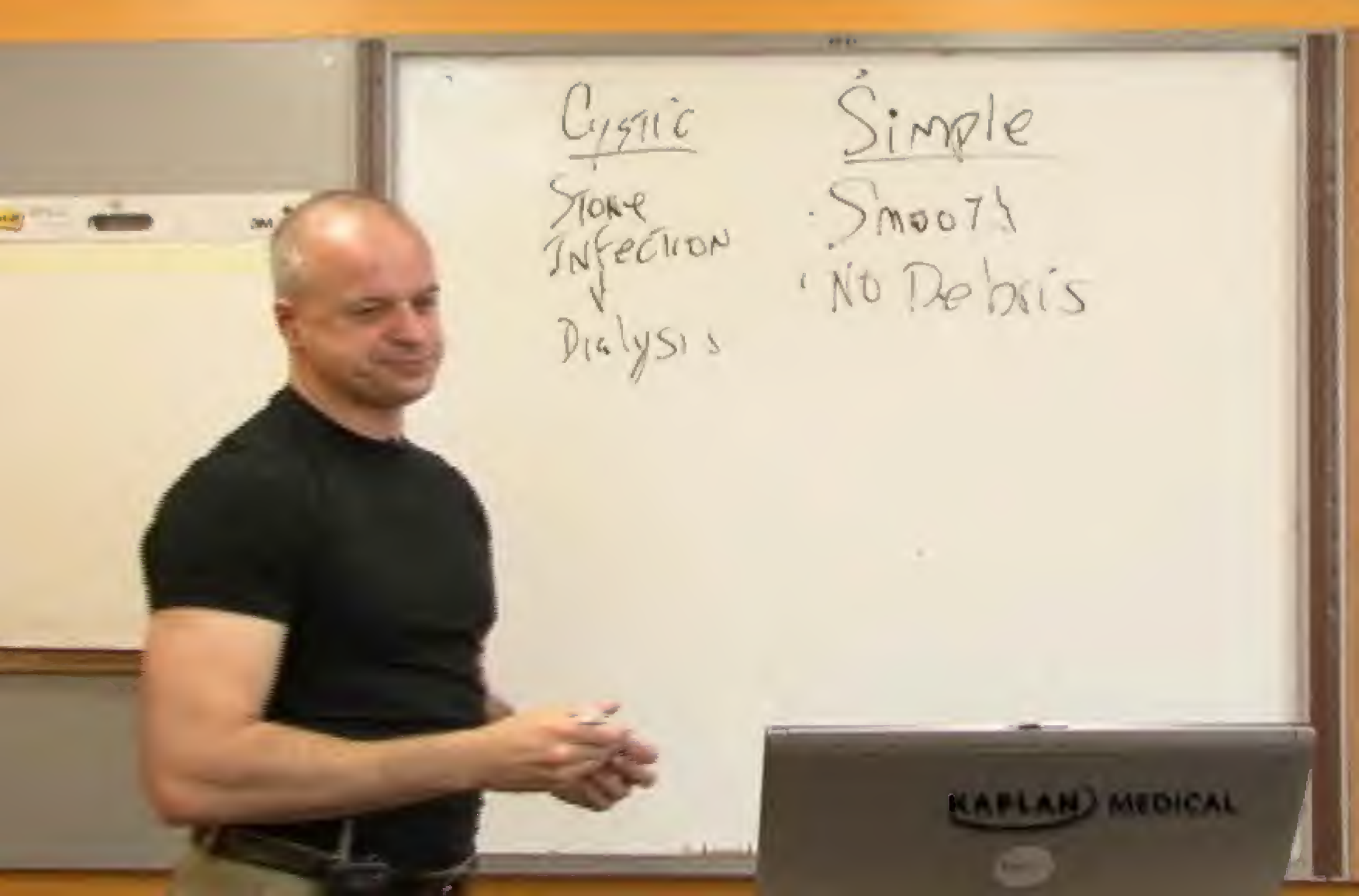
- *Etiology*
  1. Genetic
  2. Pathogenesis is uncertain
- *Presentation*
  1. Flank pain, hematuria (microscopic or gross), infections and calculi
  2. May be asymptomatic
  3. Extra-renal manifestations includes
     - Hepatic cysts → 40-60%
     - Colonic diverticula
     - Hypertension → 50%
     - Mitral valve prolapse → 25%
     - Intracranial aneurysm → 10-20%

Adult Polycystic Kidney Disease

- *Diagnosis*
  1. Ultrasound and CT scan
- *Treatment*
  1. Nonspecific
  2. Manage complications

Simple Renal Cyst

- Very common
- Represent **65-70% of all renal masses**
- Smooth-walled with no debris → expectant management
- Irregular-walls or debris → aspiration to exclude malignancy


Cystic
Stone
Infection
Dialysis
Simple
Smooth
No Debris
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Essential Hypertension

- In the **normal population** (i.e. NO diabetes and NO renal disease)

  Systolic > 140

  or

  Diastolic >90

- Discovered on multiple readings in the absence of a specific etiology

Avoid "White-Coat Hypertension"

- Allow the patient to sit quietly for 5 mins
- NEVER label a patient as hypertensive with one reading
- Repeat 3-6 times over several months before confirming the diagnosis and initiating therapy

Essential Hypertension

- In **diabetics** and those with **renal disease**

  Systolic > 130

  or

  Diastolic >80

- In addition → those with **BP > 160/110 must receive two-drug therapy**

Essential Hypertension

- Presentation
  1. Most common → asymptomatic patient with elevated BP found on routine screening
  2. When symptoms are present
     - Acute → hypertensive emergency
     - Long-term → end-organ damage
     - Secondary HTN → concomitant symptoms

Essential Hypertension— Labs

- Focus → evaluate for end-organ damage and rule-out secondary causes
  1. Urinalysis
  2. Hematocrit
  3. Serum potassium
  4. Serum BUN and Cr
  5. ECG
  6. Blood glucose
  7. Plasma lipids

Classification and Treatment Guidelines

Class	*Systolic*	*Diastolic*	*Lifestyle Mod.*	*Drug therapy*
Pre-HTN	120-139	80-89	Yes	Only if (+) end-organ damage
Stage 1 HTN	140-159	90-99	Yes	Yes
Stage 2 HTN	>160	>100	Yes	Two-drug regimen

Drug of Choice?

- Initial treatment
  1. ***Diuretic*** → mortality benefit
  2. If diuretics fail → add a second drug
     - Beta-blocker
     - Calcium-channel blocker
     - ACE inhibitor
     - Angiotensin-receptor blocker

Individualized Treatment

- *Diabetics*
  1. ACE inhibitors or angiotensin-receptor blockers
- *Post-MI*
  1. Beta-blocker
- *Decreased left-ventricular systolic function*
  1. ACE inhibitor and/or beta-blocker
- *Pregnancy*
  - α-methyldopa, labetalol, hydralazine or calcium-channel blockers
  - ACE-inhibitors and angiotensin receptor blockers are a NO-NO!!!!
  - Diuretics are relatively contraindicated

Long-term Complications

- Cardiac → Acute MI, CHF, left-ventricular hypertrophy, aortic aneurysm, and dissection
- Cerebrovascular → TIA or stroke
- Renal → proteinuria , microscopic hematuria, increased BUN/Cr, CRF
- Retinopathy → Hemorrhages, exudates, arteriolar narrowing, and papilledema

Hypertensive Emergency— An Overview

- Cardiac, neurologic, renal, and retinal involvement
- Diastolic typically **> 120-130 mmHg**
- *Symptoms* → headache, dizziness, chest pain, dyspnea, blurry vision, and palpitations
- *Signs* → Evidence of stroke, subarachnoid hemorrhage, encephalopthy, myocardial ischemia, papilledema

Hypertensive Emergency—Diagnosis

- White-coat syndrome is NOT a concern given clear-cut symptoms
- CT scan of the head → rule-out or rule-in hemorrhage
- ECG → rule-out or rule-in acute MI

Hypertensive Emergency—Treatment

- **IV nitroprusside and labetalol are the two drugs of choice**
- Nitroglycerin if (+) myocardial ischemia
- IV Enalaprilat, esmolol, diazoxide and trimethaphan are also used
- **DO NOT LOWER TOO FAR!!**
  1. Stay above a diastolic of **95-100 mmHg**

Secondary Hypertension

- Who should be screened?
  1. Those who are very young or very old
  2. Those with key features of a particular cause
  3. Hypertension refractory to therapy

Renal Artery Stenosis

- *Etiology*
  1. Elderly → atherosclerotic disease
  2. **Young → fibromuscular dysplasia**
- **Findings**
  - **Abdominal bruit that radiates laterally** (50-70% of patients)

Renal Artery Stenosis

- *Diagnosis*
  1. **Best initial test** is an **ultrasound**
  2. Captopril renogram
  3. **Arteriogram** is best to **confirm** the diagnosis
  4. Duplex ultrasound (accuracy is operator dependant)
  5. MRI angiography
- Best initial treatment is **percutaneous transluminal angioplasty** → If failure occurs → repeat stenting → failure stills occurs? → surgical correction → surgical correction fails? → ACE inhibitors

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Primary Hyperaldosteronism (Conn Syndrome)

- *Etiology*
  1. Most common cause → **unilateral adenoma** (sometimes bilateral)
  2. Remaining cases due to bilateral hyperplasia
- Cancer is rare
- *Presentation*
  - **Hypertension (+) hypokalemia** with or without symptoms

Primary Hyperaldosteronism (Conn Syndrome)

- *Diagnosis*
  1. Elevated serum and urine aldosterone
- *Treatment*
  - Adenoma → surgical resection
  - Hyperplasia → potassium-sparing diuretics

Pheochromocytoma

- *Etiology*
  1. Most common cause is a benign adrenal tumor.
  2. Rule of 10's: 10% bilateral, 10% malignant, 10% extra-adrenal
- *Presentation*
  - **Episodic HTN with headache, sweating, palpitations and tachycardia**

Pheochromocytoma

- *Etiology*
  1. Most common cause is a benign adrenal tumor.
  2. Rule of 10's: 10% bilateral, 10% malignant, 10% extra-adrenal
- *Presentation*
  - **Episodic HTN with headache, sweating, palpitations and tachycardia**

Cushing Disease

- *Etiology*
  1. Most common cause is ACTH hypersecretion secondary to a **pituitary adenoma**
- *Presentation*
  - **Hypertension with Cushingoid features**
    - Truncal obesity, buffalo hump, menstrual abnormalities, striae, impaired healing

Other Causes of Secondary Hypertension

- Coarctation of the aorta
  1. Key feature is **BP > in the upper extremities versus the lower extremities**
- Other causes
  1. **Oral contraceptives**
  2. Acromegaly
  3. Congenital adrenal syndromes
  4. Chronic renal disease

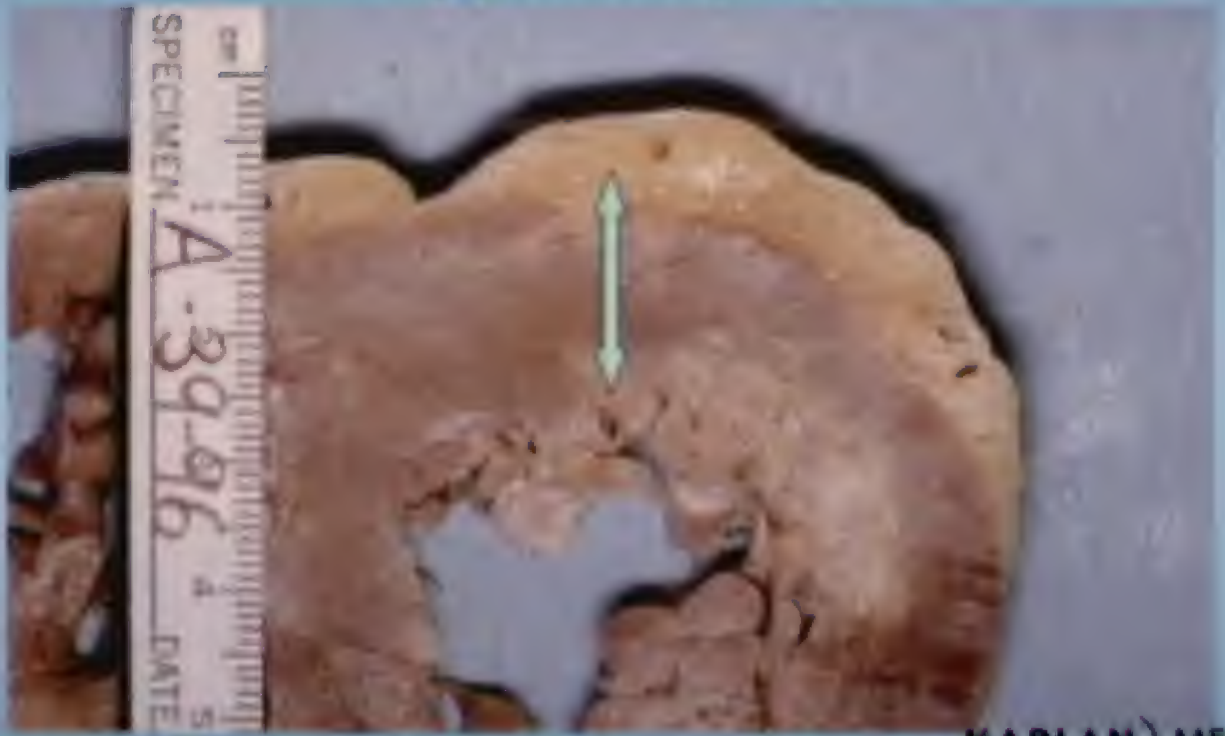
Antihypertensive Medications—Diuretics

Thiazides	Loop Diuretics	Potassium Sparing
HCTZ	Furosemide	Spironolactone
Chlorthalidone	Bumetanide	Amiloride
Metolazone	Torsemide	Triamterene
Indapamide		

Antihypertensive Medications

- β-Blockers
- ACE-inhibitors
- Calcium-channel blockers
- Angiotensin receptor antagonists
- Central-acting sympatholytics
- Direct vasodilators
- α-adrenergic blockers

Complications— Left Ventricular Hypertrophy



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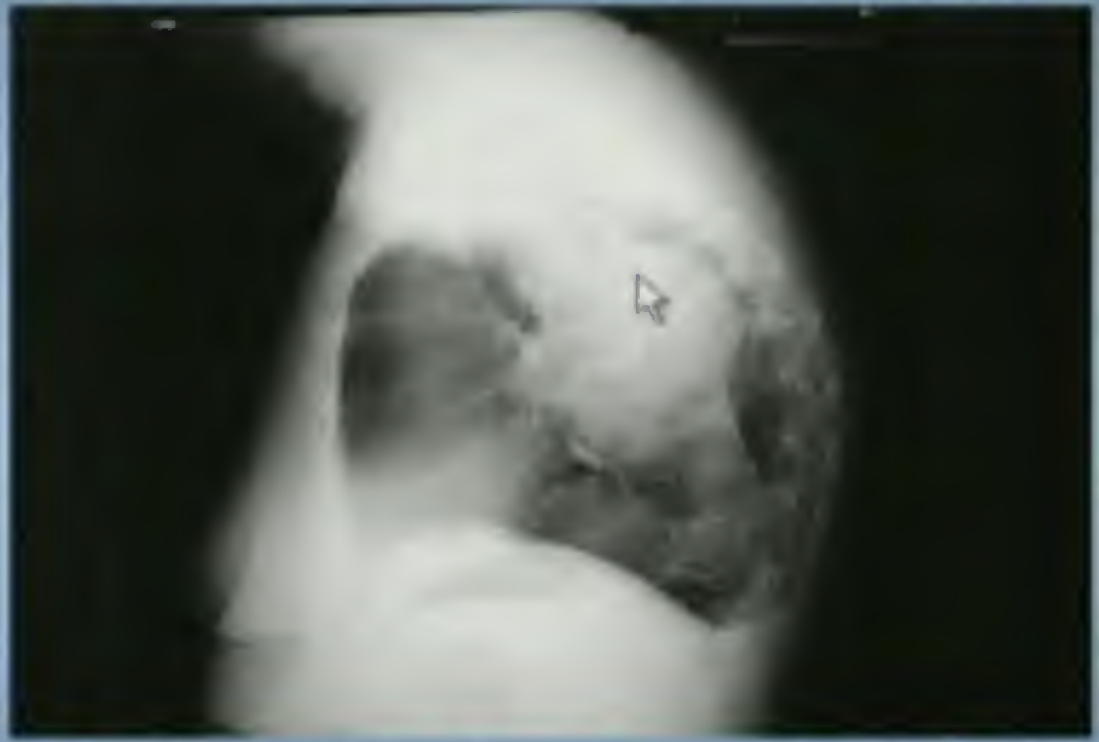
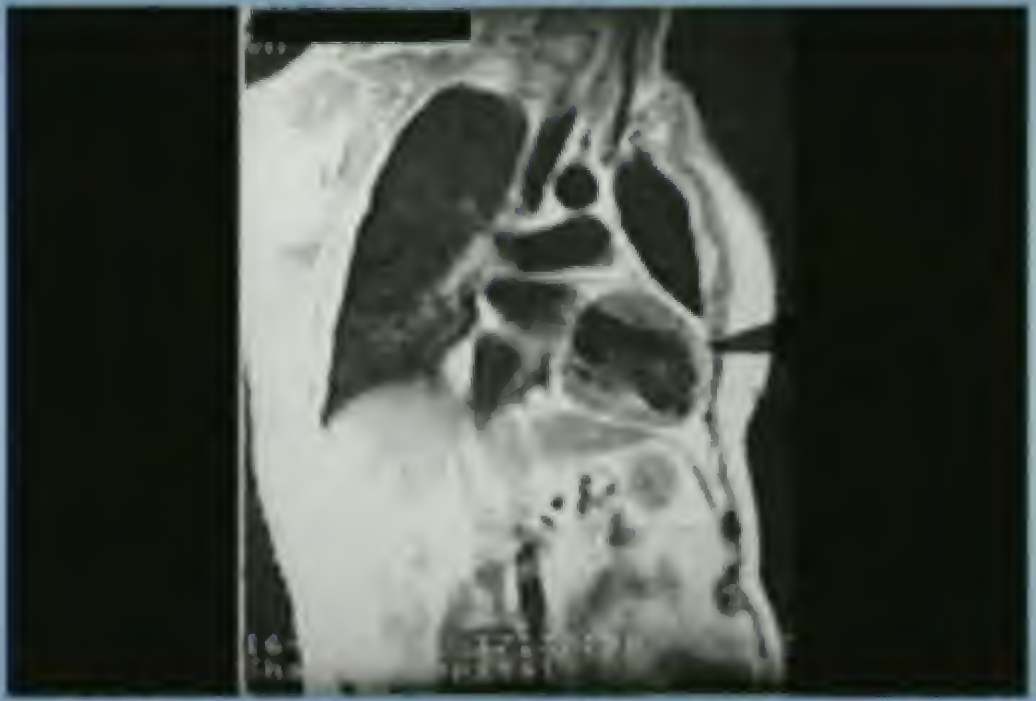
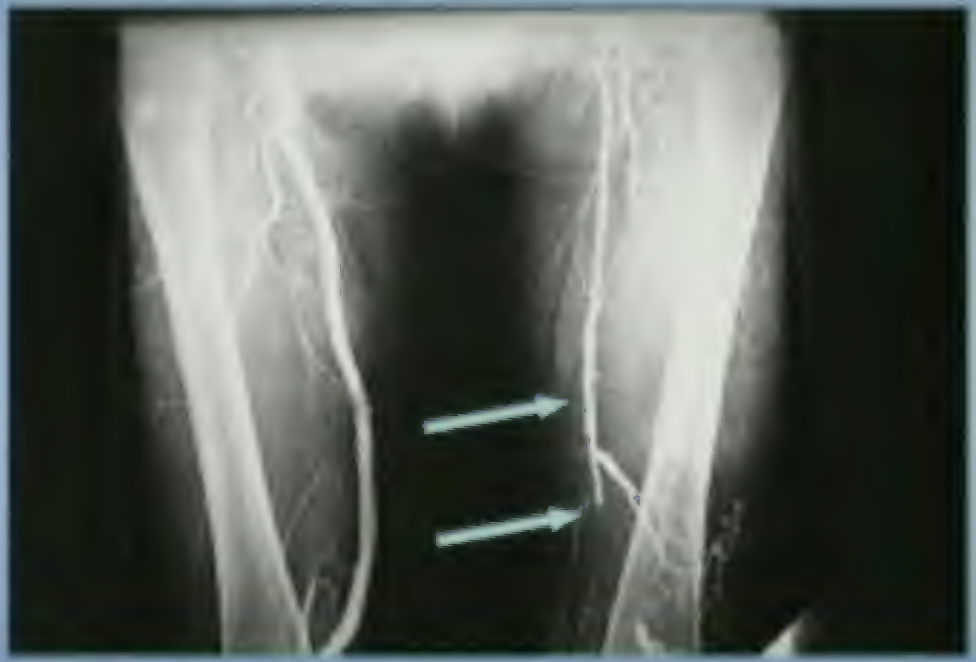
Complications— Aortic Aneurysm



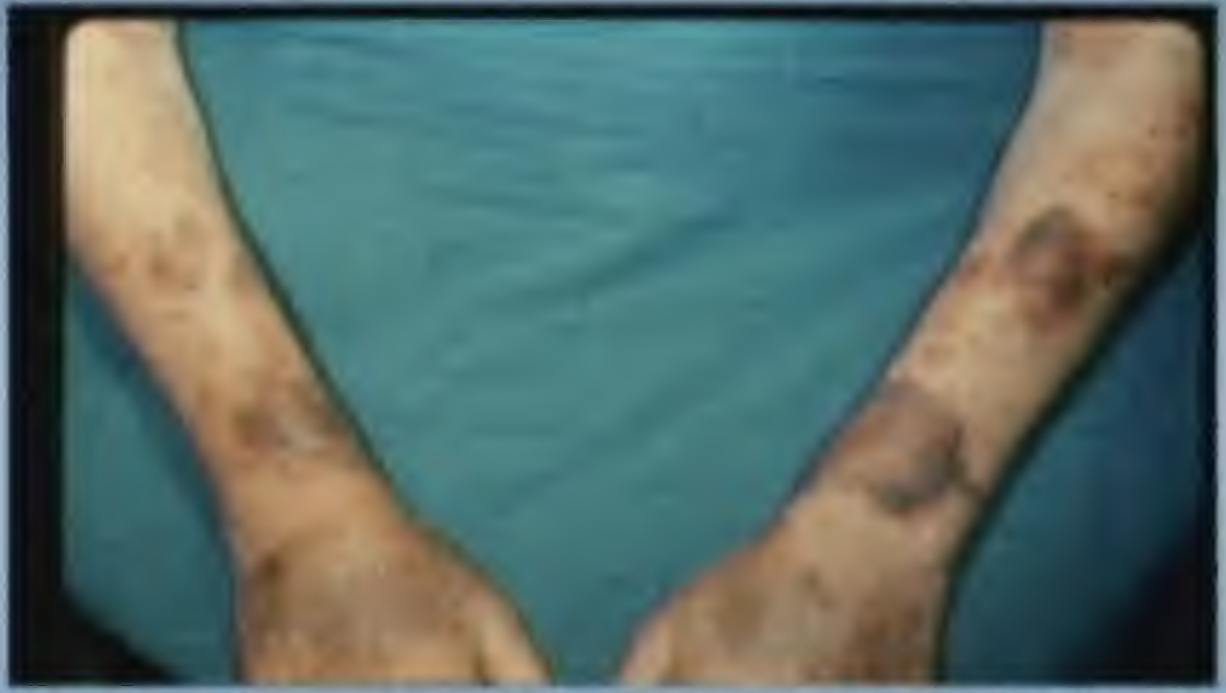
Complications— Myocardial Infarction



Complications— Peripheral Vascular Disease



Cushing Disease— Ecchymosis



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Cushing Disease— Moon Facies

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